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## **SAVEWS Jr. User's Manual, Version 1.0**

Bruce Sabol, Eddie Melton, Deborah Shafer, Jessie Jarvis,  
Steve Evert, and Richard Loyd

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Final report

Approved for public release; distribution is unlimited.

## Abstract

This user's manual describes components, assembly, system configuration, data collection procedures, and data processing activities for the second iteration of the Submersed Aquatic Vegetation (SAV) Early Warning System (SAVEWS Jr.). SAVEWS Jr. uses two frequencies (200- and 800-kHz) from a downward-aimed echo sounder to determine the bottom depth and presence/absence of SAV. If SAV is present, canopy height and vegetation percent coverage are estimated. Once collected, the digital data (Lowrance proprietary .SL2 files) are displayed, using the SAVEWS Jr. software. Users then select a configuration file that is appropriate to the environment sampled. A general version of this file is provided with the installation software to serve as a starting point for users to develop their own customized files.

After initial processing, a display of classified output (bottom depth and canopy top) is superimposed on the colorized echogram and aligned with data plots of canopy height and percent coverage. Beyond quality assurance graphics, the primary output of SAVEWS Jr. is the .SDF file (SAVEWS data file) which is an ASCII, comma-delimited file containing position-referenced classified output. This can be used directly in statistical analyses or mapping software.

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# Contents

<b>Abstract .....</b>	<b>ii</b>
<b>Figures and Tables .....</b>	<b>iv</b>
<b>Preface .....</b>	<b>vi</b>
<b>1 Introduction .....</b>	<b>1</b>
<b>2 Components .....</b>	<b>3</b>
Installation, setup, and operation .....	3
Connecting components .....	5
System power-up and memory card insertion .....	9
System configuration .....	10
Recording .....	11
<b>3 Designing and Conducting a Survey .....</b>	<b>13</b>
Environmental conditions .....	15
Tidal effects .....	16
Wind effects .....	16
Setting waypoints .....	17
Navigating transects .....	18
Conducting a survey .....	19
Data file naming convention .....	20
<b>4 Software Installation and Setup .....</b>	<b>22</b>
<b>5 Version Notes (Version 1.0) .....</b>	<b>24</b>
Processing .....	24
SAVEWS Jr. processor .....	25
Post processing .....	37
<b>6 Caveats and Limitations .....</b>	<b>42</b>
<b>7 Point of Contact .....</b>	<b>45</b>
<b>References .....</b>	<b>46</b>
<b>Appendix A: Assembling a Self-Contained SAVEWS Jr. Field Unit .....</b>	<b>47</b>
<b>Appendix B: Configuration File -DEFAULT.sjrcfg .....</b>	<b>52</b>
<b>Appendix C: Suggested Field Datasheet .....</b>	<b>56</b>
<b>Appendix D: Description of Acoustic Percent Coverage .....</b>	<b>58</b>
<b>Report Documentation Page</b>	

# Figures and Tables

## Figures

Figure 1. Lowrance HDS-10 console and 200-kHz skimmer transducer.....	4
Figure 2. StructureScan sonar and transducer.....	4
Figure 3. External GPS antenna and cabling.....	5
Figure 4. Connecting power to HDS console.....	6
Figure 5. Connecting skimmer transducer cable to HDS console.....	6
Figure 6. Connecting power to LSS-2 sonar module.....	7
Figure 7. StructureScan power cabling; note connected yellow wires. ....	7
Figure 8. Structure Scan transducer cabling.....	8
Figure 9. Connecting LSS-2 sonar module with HDS.....	8
Figure 10. Connecting external GPS to HDS.....	9
Figure 11. Inserting memory card (notch down).....	9
Figure 12. Uni-directional parallel transects. ....	14
Figure 13. Bi-directional parallel transects are surveyed in opposing directions. ....	15
Figure 14. Colorized echogram of acoustic transect at Cuttyhunk Harbor, MA. ....	26
Figure 15. SAVEWS_Jr data processing window, <i>Generate output image</i> is on by default. ....	27
Figure 16. Processing GUI filled in and ready to start program. ....	27
Figure 17. Display during processing.....	27
Figure 18. Graphic of processed output generated from a non-optimized CF (DEFAULT.sjrcfg). ....	28
Figure 19. Raw output file (.SDF); a. processing parameters, and b. processed data. ....	29
Figure 20. Reprocessing file 20120626_134202 with usernoise=160. ....	32
Figure 21. Colorized echogram of acoustic transect of Eurasian watermilfoil in northern Wisconsin. ....	33
Figure 22. Processed output generated from a non-optimized CF (DEFAULT.sjrcfg).....	34
Figure 23. First reprocessing file 20110902_145734 (usernoise=115, startdepth=0.3) designed to improve vegetation detection performance. ....	35
Figure 24. Second reprocessing file 20110902_145734 (bot_change_tol = 0.10m) designed to smooth erratic bottom depth declarations. ....	36
Figure 25. Tide data file must contain integer month and day, decimal hours local time, and tide (ft).....	37
Figure 26. The list file must contain SDF filenames, in date_time format, transect ID #, depth of transducer face (m), and replicate #. ....	38
Figure 27. Waypoint file for computing location along transect. ....	38
Figure 28. FINALIZE graphic user interface window after executing program.....	40
Figure 29. Example output of FINALIZE program (Output.CSV).....	41
Figure A1. Portable SAVEWS Jr. System. ....	48

Figure A2. LSS-2, 12-V power source and wiring. ....	48
Figure A3. Quick disconnect mount external connections. ....	49
Figure A4. External power connection. ....	49
Figure A5. Transducers, mounted on pivot arm, and GPS antenna mounting bracket. ....	50
Figure A6. Transducer and GPS bracket in use. ....	50
Figure D1. Acoustic survey cartoon and computation of outputs using 10 pings per report cycle. ....	59
Figure D2. Hypothetical comparison of diver and acoustic measurements for a 2.5-m linear segment of SAV. ....	60
Figure D3. Comparison of interpreted underwater videography and SAVEWS acoustic system in a mixed seagrass bed in southwest Florida. ....	61

## Tables

Table 1. Hardware components required for SAVEWS Jr. ....	4
Table 2. Definition of output variables form raw output file (.SDF). ....	30
Table 3. Definition of output variables from FINALIZE program. ....	41
Table A1. Components of example self-contained SAVEWS Jr. system ....	51

## Preface

The work reported herein was conducted as part of the Aquatic Plant Control Research Program (APCRP). The APCRP is sponsored by Headquarters, US Army Corps of Engineers (HQUSACE), and is assigned to the US Army Engineer Research and Development Center (ERDC) under the purview of the Environmental Laboratory (EL), Vicksburg, Mississippi. The APCRP is managed under the Civil Works Environmental Engineering and Sciences Office, Dr. Alfred F. Cofrancesco, Technical Director. Dr. Linda S. Nelson is Program Manager of the APCRP.

The Principal Investigator for this work was Bruce M. Sabol, Environmental Systems Branch (ESB), Ecosystem Evaluation and Engineering Division (EEED), US Army Engineer Research and Development Center - Environmental Laboratory (EL). This work was performed under the general supervision of Dr. Beth Fleming, Director, EL; Dr. Jack Davis, Deputy Director, EL; Edmond Russo, Chief, EPED; and Mark Graves, Chief, ESB.

COL Jeffrey R. Eckstein was the Commander and Executive Director of ERDC, and Dr. Jeffery P. Holland was Director.

# 1 Introduction

Automated processing of digital echo sounder data has proven to be useful for depth and canopy characterization in beds of submersed aquatic vegetation (SAV). The first version of this capability, SAVEWS (Submersed Aquatic Vegetation Early Warning System), released in 2001 (Sabol et al. 2002), required an expensive calibrated scientific echo sounder that was beyond the financial means of many resource agencies. Consequently, the system was underutilized by agencies that would have benefited from SAVEWS data. Since then, consumer-grade marine electronics have advanced to the point they have many of the same features as the high-cost scientific echo sounders for a fraction of the cost. The low-cost marine electronics market was surveyed and a widely used echo sounder/GPS system (HDS-x, Lowrance Electronics, Tulsa, Oklahoma) with digital recording capability was selected as a good candidate for automated processing. This system is designated as SAVEWS Jr. The primary difference between SAVEWS Jr. and the previous SAVEWS code is that the low-cost systems are not calibrated and simultaneously use two different frequencies. This necessitated a fundamentally different approach to the processing. The signal processing code developed was necessarily written around the data formats and characteristics of the Lowrance HDS system. Selection of this system does not constitute endorsement by the government. Potentially, other vendors' equipment could also be used although required code modification may be significant. The current version of the processing software is written in MatLab to facilitate rapid code development, at the expense of slightly slower execution times. As the code matures, the final version of MatLab will either be optimized for faster execution or it will be rewritten in a different language. These modifications will correspond to subsequent software releases beyond Version 1.0.

This user's manual describes components, assembly, system configuration, data collection procedures, and data processing. The goal is to make this a stand-alone technology that can be operated by scientists and field personnel involved with SAV mapping. The system uses two frequencies (200- and 800-kHz) from a downward-aimed echo sounder. The frequencies are processed to determine the bottom depth and presence/absence of SAV. If SAV is present, the frequencies are used to estimate the canopy height and vegetation percent coverage. The key to processing

acoustic data for SAV is to correctly locate the bottom, particularly when SAV is present. Using two frequencies resulted in better bottom tracking relative to the earlier one-frequency SAVEWS. Once collected, the digital data (Lowrance proprietary .SL2 files) are displayed, using the SAVEWS Jr. software. The user will then select a configuration file that is appropriate to the environment sampled. This file will set a host of algorithm parameter values used within the software. A general version of this file is provided with the installation software. This will serve as a starting point for users to develop their own customized files. The installation software also provides some examples of how configuration files are set; the authors of this report can provide assistance in developing these files in particularly difficult cases.

After initial processing, a display of classified output (bottom depth and canopy top) is superimposed on the colorized echogram for review by the user. This is aligned with data plots of canopy height and percent coverage. The user then ascertains whether these outputs reasonably represent conditions evident in the colorized echogram file. If not, the file can be rerun after selecting different configuration values. Beyond quality assurance graphics, the primary output is the .SDF file (SAVEWS data file) which is an ASCII, comma-delimited file containing position-referenced classified output. This can be used directly in statistical analyses or mapping software.

## 2 Components

Required components for the SAVEWS Jr. system are listed in Table 1 and illustrated in Figures 1-3. All except the external Global Positioning System (GPS) and its supporting network cable are mandatory. This set of components allows a relatively wide-beam, 200-kHz and the narrow-beam downlooking 800-kHz (or 455-kHz) signal to be simultaneously collected. The HDS system has an internal GPS but the external GPS provides greater positional accuracy and data rate, and allows the antenna to be positioned independent of the HDS system. This makes it possible to position the GPS antenna directly over the transducer and to more precisely navigate planned transects since the output rate is five times as fast, resulting in less lag in navigation guidance.

### Installation, setup, and operation

Brief instructions for equipment setup are provided. Users are encouraged to download and read detailed installation and setup instructions available for each recommended component from the Lowrance website ([www.Lowrance.com/en/Downloads/Manuals/](http://www.Lowrance.com/en/Downloads/Manuals/)). Transom mounting, as suggested in the Lowrance manual, is very convenient because the transducers are permanently affixed to the boat and the only thing needed to conduct a survey is a fresh SDHC data card. However, two problems can be created with this technique: 1) the side lobe of the Structure Scan can “see” the lower unit of the outboard motor, if not trimmed properly, creating an artifact in the recorded data, and 2) the two transducers are not laterally aligned; therefore, they sample different bottom areas during data collection. If not yet installed, users are encouraged to consider another mounting technique, such as the transducer mount system illustrated in Figure A5, mounted on the bow. Instructions for assembling the entire system in a self-contained field-portable container, ideal for rapid deployment to any boat, are contained in Appendix A. The advantage of the self-contained unit is that assembly or connection will not be required each time the system is used.

Table 1. Hardware components required for SAVEWS Jr.

Component	Description	Part #A	CostB	Note
Echo sounder with internal GPS system	Lowrance HDS-10 (or HDS-7 or 8 with smaller screen and lower cost) with 200-KHz (20-deg) skimmer transducer with built-in temperature sensor	000-0140-00	\$2,500	Available from multiple sources
SDHC cards	8 GBytes			
External SDHC card reader				If not on PC
Side scan transducer	Lowrance 132-06 StructureScan Sonar option for HDS with 455- and 800-KHz transducers	LSS-2	\$600	
External GPS	Lowrance high-sensitivity GPS receiver antenna with N2K cable and T connectors	LGC-4000-CE (000-0125-28)	\$200	

A. <http://store.navico.com> part numbers B. Approximate cost as of May 2012.

Figure 1. Lowrance HDS-10 console and 200-kHz skimmer transducer.



Figure 2. StructureScan Sonar and transducer.





Figure 3. External GPS antenna and cabling.



## Connecting components

The process for connecting components is as follows:

1. Connect the HDS power cable to the blue PWR/DATA plug on the back of the HDS (Figure 4) and a +12-V battery. Cigarette lighter connectors should be avoided, as they can easily lose connection, requiring that the entire system be reset.
2. Connect the skimmer transducer cable to the blue SONAR plug on the back of the HDS (Figure 5).
3. Connect the StructureScan power cable to the 12-V source and to the black POWER plug on the back of the LSS-2 Sonar module (Figure 6). Make sure that the yellow wire on the StructureScan power cable at the battery is connected to the yellow wire on the HDS power cable at the battery (Figure 7). This will allow the StructureScan to be turned on with the main HDS power button.
4. Connect the StructureScan transducer cable to the black SONAR plug on the back of the LSS-2 Sonar module (Figure 8).
5. Connect the communication link between the LSS-2 Sonar module and the HDS. The cable with the yellow plugs gets connected to ENET port #1 on the LSS-2 module and the yellow ENET plug on the back of the HDS (Figure 9).
6. Connect the pre-configured GPS network cable (see Lowrance NMEA 2000 Network Installation Instructions [[www.lowrance.com/Downloads/Manuals](http://www.lowrance.com/Downloads/Manuals)]) to the GPS antenna and to the black NMEA 2K plug on the back of the HDS (Figure 10).
7. Attach the power connections on the pre-configured GPS network cable to the battery.

8. System components are now correctly connected. Before proceeding to the next step (power up and configuration), submerge the transducers in water. While this step is not required by Lowrance, it is a generally recommended practice to protect hydroacoustic transducers from damage.

Figure 4. Connecting power to HDS console.

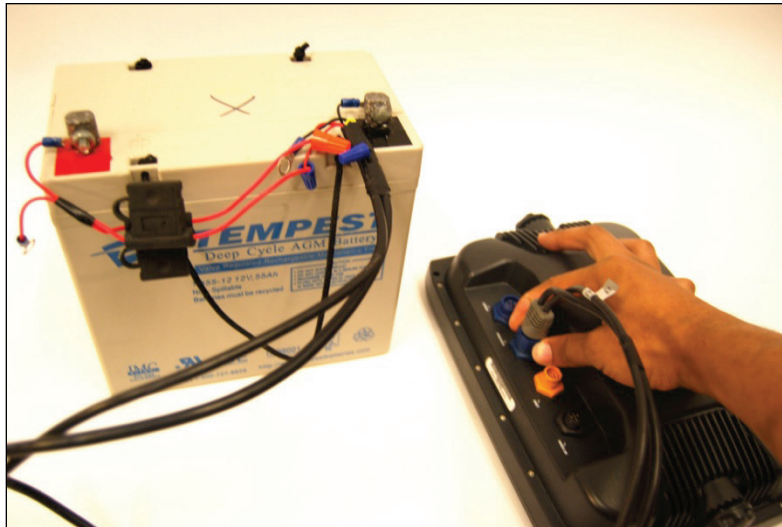


Figure 5. Connecting skimmer transducer cable to HDS console.



Figure 6. Connecting power to LSS-2 Sonar module.



Figure 7. StructureScan power cabling; note connected yellow wires.

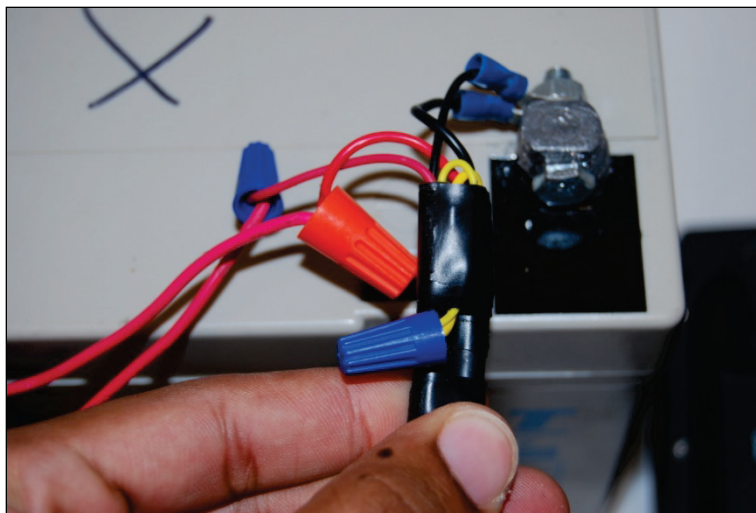


Figure 8. Structure Scan transducer cabling.



Figure 9. Connecting LSS-2 Sonar module with HDS.

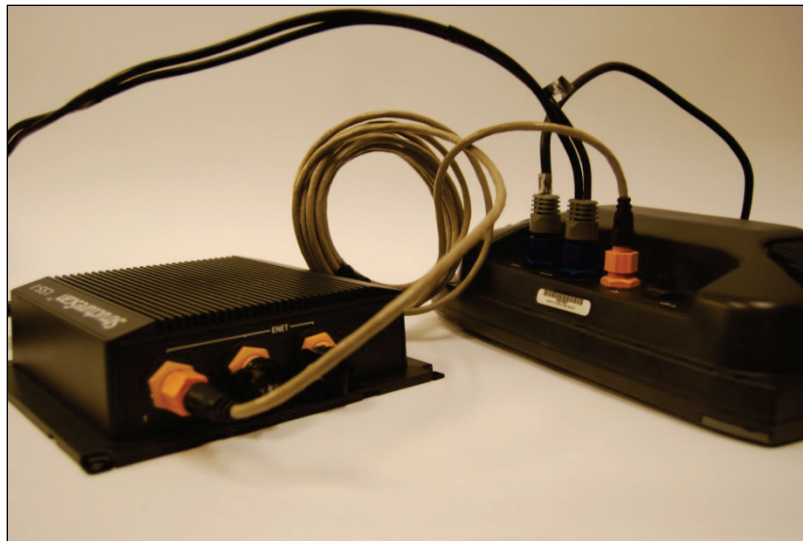




Figure 10. Connecting external GPS to HDS.



## System power-up and memory card insertion

The processes for power-up and memory card insertion are outlined below. Numbering of these steps continues from the previous section.

9. The HDS console is used to configure the system for use (Figure 1).
10. Power on the HDS by pressing the LIGHT/POWER button on the lower right corner of the HDS front.
11. Dismiss the warning (button on bottom row under “Accept”).
12. Insert one or more SDHC memory cards into the slots under the door at lower right of HDS front (Figure 11).  
Card #1 goes on the right and card #2 goes on left, with notch side down.
13. Press “Pages” button on right side of HDS face.
14. Use multi-directional pad to page over to “Waypoints, routes, trails,” then move to “Files.”
  - a. Press Enter button on right side of HDS.
  - b. Make sure the memory card(s) is recognized by HDS. Card listings will be at the top of the screen. If a card is not listed, eject and reinsert until HDS recognizes the card.
15. Press Exit on the right side of the HDS. Memory card(s) are now inserted and ready to receive data.

Figure 11. Inserting memory card (notch down).



## System configuration

200-kHz transducer. Configuration of the 200-kHz transducer is described below. Numbering of these steps continues from the previous section.

16. Press “Page,” then scroll over to top heading “Sonar,” then down to subheading “Sonar,” and press Enter. Sonar echogram display will be activated.
17. Press Menu (right side of HDS).
  - a. Set “Range” to maximum depth expected in survey (system actually records to twice user-set depth), do not use Auto Range for recording.
  - b. Set “Frequency” to 200 KHz.
  - c. Set “Ping Speed” to 10.
  - d. Click (press Enter) at “Sonar Options.”
    - i. Fish ID – off.
    - ii. Fish ID beeps – disabled (circle not filled in).
    - iii. Click “Exit” to return to Sonar window.
  - e. Click on “Settings” at bottom of menu.
    - i. Press Enter.
    - ii. Go to “Sonar,” (press Enter) and configure as follows:
      - 1) Network Sonar – enabled (circle filled in).
      - 2) Noise Rejection – off.
      - 3) Surface Clarity – off.
      - 4) Manual Mode – enabled (circle filled in).
      - 5) Fishing Mode – general use.
18. Press “Exit” twice.
19. Verify that Sonar is in operation (data scrolling); if not scrolling, make sure “Stop Sonar” is not highlighted. Transducer configuration is now complete.

StructureScan transducer. Configuration of the StructureScan transducer is described below. Numbering of these steps continues from the previous section.

20. Press “Pages” button on right side of HDS face
21. Use multi-directional pad to page over to “Structure,” then down to “Structure and Sonar,” and press Enter. Verify that the sidescan echogram

is on and scrolling on the screen. If it is not, make sure SONAR STOP (from Menu) has not been activated. If still no scrolling, recheck cabling and battery power.

22. Press Menu, then configure as follows:

- a. Set RANGE to expected maximum depth (**do not use Auto Range for recording**).
- b. Set FREQUENCY to 800 kHz.
- c. Set VIEW to Down.
- d. Press Structure options, then configure as follows:
  - i. Set Structure surface clarity to OFF.
  - ii. Set Structure noise rejection to OFF.
  - iii. Press EXIT twice to return to data screen.

23. Configuration complete, press Exit on right side of HDS

External GPS. Configuration of the external GPS is described below. Numbering of these steps continues from the previous section.

24. On the HDS panel, press MENU, then SETTINGS, then NETWORK, then Device List to verify that HDS recognizes external GPS (LGC4000 High Sensitivity Antenna). If LGC 4000 is not listed on the device list, recheck connections, then EXIT.
25. Go to MENU/SETTINGS/NETWORK/DATA SOURCE SELECTION/GPS (right arrow)/ALL DATA (right arrow). Highlight either AUTO (selects strongest GPS signal between internal and external GPS), or LGC4000 (uses ONLY external antenna). Then press SELECT followed by CLOSE.
26. GPS output and healthy status can be seen by going to: MENU/SETTINGS/SYSTEM/SATELLITES.
27. Suggest positioning the GPS antenna directly over the StructureScan transducer.

## Recording

The recording process is outlined in the section that follows. Numbering of these steps continues from the previous section.

28. To begin recording:

- a. Press “Menu.”
- b. Go to “Log Sonar,” press Enter.

- c. Set up recording session (HDS will reset options if the steps are not followed in this order).
    - i. Choose save location (Memory card 1 or 2, **NOT Internal**).
    - ii. Set “Bytes per sounding” to 3200 (algorithm response to lower data rates is currently being investigated, but version 1.0 requires the full 3200 bytes per sounding).
    - iii. Select “Log all channels.” This will record the 200-kHz skimmer, and all three channels of the StructureScan transducer (left, right, and down), using the frequency selected in step 22b). An .sl2 file will be generated. It is acceptable to use the default file names offered by the HDS system – SONARxxxx. These file names will need to be renamed, using a date/time format as described later, before processing is done (see section titled **Data File Naming Convention**).
    - iv. Press Record to begin the recording session.
    - v. WRITE FILENAME, MEMORY CARD NUMBER, AND TIME/DATE IN FIELD BOOK (for use in renaming files).
29. Stop recording by pressing “Stop” twice.
30. At the end of the recording session, verify that files are present.
- a. Go back to “Waypoints, routes, files” from steps 13 and 14.
  - b. Go to “Files.”
    - i. Select the memory card number used to store files.
      - 1) Verify file presence.
      - 2) View file if desired (Note: Sensitivity parameter on far left of bottom row of buttons may need adjusting before data will appear).
31. Press Exit twice.
32. Shutting down: Press “Light/Power.”
33. Select Power Off and Press Enter.



### 3 Designing and Conducting a Survey

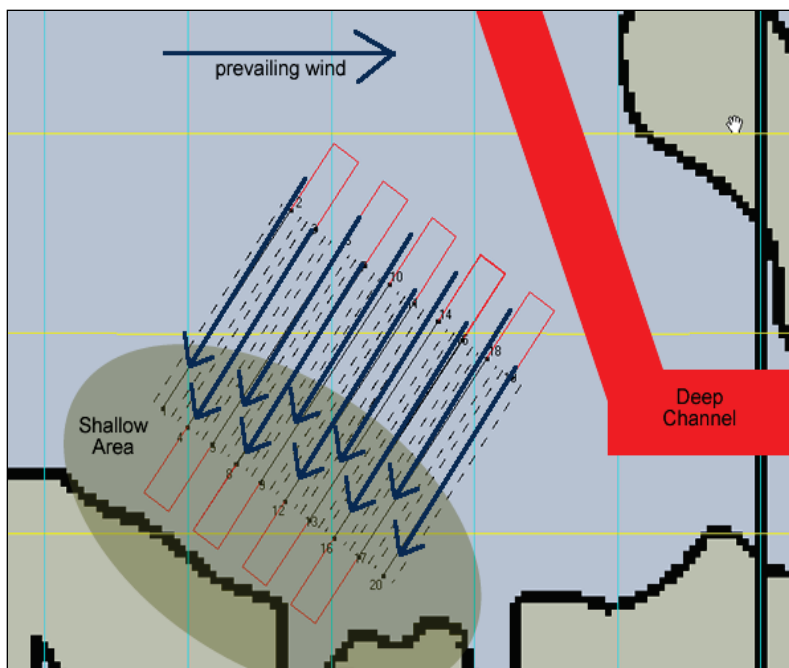
A successful operational SAV survey requires some preliminary planning. The user should select a series of parallel transects, at some fixed spacing, to be surveyed. When there is considerable depth variation in the survey area, it appears best to orient transects roughly perpendicular to the local depth contours (or shoreline). This orientation very precisely determines the depth at which SAV first occurs and makes for more accurate maps when spatial interpolation (gridding) is involved. Points needed to define these transects should be determined and entered into the HDS as GPS waypoints (see the section titled “Setting Waypoints,” which follows). Each transect can be specified by two points (beginning and ending points), or three collinear points (line up point, begin recording point, and end recording point). The CHART capability of the HDS can be used to select these points and to navigate transects. During the survey the operator should manually record filenames, transducer depth, and times and dates associated with each logged file. This will be needed in post-processing to correct for tides and generate files ready for GIS mapping. An example datasheet for logging such information is provided in Appendix C. If operating in a tidally influenced area, a measured time history of tides relative to the local vertical reference (usually Mean Lower Low Water – MLLW) will also be needed. Tidal measurements will need to be collected before, during (at least once an hour), and after the survey for each site. Vertical tidal references should be identified during the survey site selection stage.

The authors also suggest that transects should not be too long. Using the required settings, data accumulates at a rate of 8 Mb/minute; thus, a 5-minute transect will result in a 40-Mb .SL2 file. Shorter files have several advantages. First, long recording sessions are more susceptible to data loss, such as from a power flicker. Second, it will probably be necessary to process a file multiple times before the optimum configuration parameters are determined. Shorter files will save time here. Lastly, the algorithm dynamically computes thresholds needed for processing based on the acoustic conditions of the individual file. If the file is so long that conditions such as bottom composition appreciably change over the length of the transect, the resulting parameter settings may not be ideal for either condition. The authors recommend that transects be limited to no more than 5 minutes recording time. This corresponds to a roughly 600-m length at a well-suited boat speed of 4 knots. If more time is required to complete a

longer transect, one file can be closed and the next opened up quickly. Guidance is offered for two types of survey designs —repeated parallel lines in the same direction and repeated parallel lines in opposing directions.

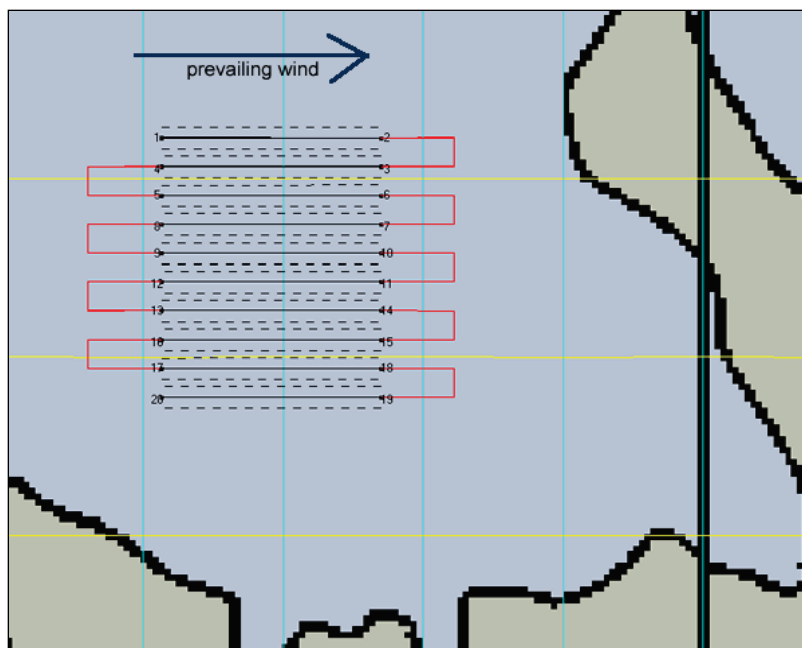
**Uni-directional parallel transects** (Figure 12) are best suited for areas where one end of the transect terminates in the shallows. A site that is bounded by a navigable channel or deeper slough to one side, and a shoreline or shoal to the other, is an example of a situation in which uni-directional parallel transects should be employed. This prevents maneuvering the survey boat in the shallows, to line up for the next transect, and possibly damage shallow-water SAV beds.

Figure 12. Uni-directional parallel transects.



**Approaches that use bi-directional parallel transects** (Figure 13) work well in areas where spatial restrictions are less significant (i.e. an area within a larger SAV bed that has little depth change and is not restricted by shoreline, shoals, or other obstacles). When designing a bi-directional survey, consider the vessel's turning capabilities and the expected local conditions (tidal flow), two factors that will help determine how far past the final collection point the vessel operator should travel before setting up for the next transect. The more time spent approaching the start-recording waypoint, the straighter the transect will be. Straight transects on a pre-planned path are particularly important for repeated surveys in the same location.

Figure 13. Bi-directional parallel transects are surveyed in opposing directions.



Regardless of method, keep the following guidance in mind:

1. End the survey line at a point that allows sufficient turning around of the vessel (i.e. not right up to a shoreline or restrictively shallow water).
2. Where a shoreline is the inside boundary of a set of lines, carefully idle back to the offshore end of the transect (i.e. conduct each line in the same direction).
3. An allowance of approximately 50 m is suggested prior to beginning a survey of the transect line to be sure the vessel operator has a correct heading, given the local conditions.
4. In the case below, consider the prevailing wind direction when establishing the track (see environmental conditions below).
5. Avoid crossing the path of the boat while recording, since the propeller entrains small bubbles in the wake that are highly reflective acoustically and can mask the intended signal (plants and bottom).

## Environmental conditions

Conditions play a large role in an operator's ability to keep the vessel on track. In coastal areas, tides and wind need to be taken into account prior to conducting the survey.

## Tidal effects

1. When unfamiliar with an area, deploy an anchor attached to a floating crab-trap-type buoy to visually observe the direction of the tidal flow.
2. If the flow is perpendicular to the transect lines, account for this in the vessel heading and angle the vessel along the line with the bow turned into the tide. Following the GPS navigation guidance on the HDS CHARTS window will show the true track of the boat and allow the operator to make needed corrections.
3. If possible, run the transect line either into (preferred) or with the tide.
4. Adjust vessel power to maintain a nearly constant speed over ground (SOG) – a range of 2-6 knots is suggested.
  - a. Decrease engine RPM when running with the tide.
  - b. Increase engine RPM when running against the tide.
5. Strong tidal flow causes SAV canopies to lay down in the direction of flow, greatly reducing the in situ canopy height. If accurate measures of in situ canopy height are important, then it would be highly desirable to schedule the survey during high slack tide. Vegetation percent coverage is not too sensitive to plants lying over due to tidal currents.

## Wind effects

Depending on the survey vessel's susceptibility to wind (cabin versus non-cabin vessels), wind may affect the path along the given transect line.

1. If possible, run the transect line either into (preferred) or with these forces.
2. Adjust vessel power to maintain a nearly constant speed over ground (SOG).
  - a. Decrease engine RPM when with the wind.
  - b. Increase engine RPM when against the wind.
3. For those not familiar with the handling characteristics of the vessel, several practice transects are recommended.
  - a. Note speed and direction of deviations from transect lines and record this information in the field notebook.
  - b. Correct for deviations while conducting the survey by adjusting speed.

In addition to navigational challenges, wind affects acoustic conditions within the upper water column. Wind, and resulting waves, entrain small bubbles in the upper water column. These highly reflective bubbles may mask the “quiet zone” necessary for detecting submersed vegetation. This is not a problem in deep waters, except for the boat heave effects on the detected bottom depth. In shallow waters, the loss of the quiet zone may make plant detection impossible. Strong (>10 knots), steady winds may make it necessary to reschedule sampling activities.

## Setting waypoints

Transect waypoints are specified by latitude/longitude pairs. Two waypoints are minimally needed to define each transect. It may be desirable to specify each transect using three waypoints — the first being a line-up point, followed by the start-recording and the stop-recording points. Transect points may be selected in two ways – using digital (or paper) maps (including the HDS CHART), and field selection during a preliminary site visit. If time is available, the second method is of course preferred because it allows users to see conditions that may not be evident from a map. All waypoints should be entered and saved into the HDS as GPS waypoints.

Map selection of waypoints: Prior to field work, obtain a chart or use the HDS chart to select field sites, and then follow the process outlined below.

1. If using the HDS chart, open the Chart page.
2. Place the cursor on the Chart page at the desired location to set the waypoint, and select New Waypoint.
3. When the New Waypoint menu appears, select Save.

If using latitude and longitude values selected from an external chart, go to the Utilities page.

1. Go to the Waypoints screen.
2. To open the Waypoints screen menu, press the MENU key from the Waypoints screen.
3. Select New.
4. From this screen, type in latitude and longitude as well as the waypoint name. Hit enter.
5. Double-check the position of the Waypoint on the Chart screen.

Field selection of waypoints:

1. Position the survey vessel 50 m away from selected waypoint position. Motor towards the beginning of the survey transect.
2. Press the MENU key (soft key). From the Chart menu, select New Waypoint.
3. When located over the beginning of the transect, begin the process to save the Waypoint. When the New Waypoint at Vessel menu appears, select Save.
4. Record the site name, transect number, waypoint number, and GPS position in a field notebook.
5. Repeat these steps for all waypoints.

To delete waypoints:

1. From the Pages screen, select waypoints, routes, and trails, and press ENTER.
2. When the waypoints screen appears, select a waypoint to navigate to from the waypoints list, and press MENU.
3. The waypoints screen will appear. Press the Edit soft key.
4. From the Edit Waypoint menu, select Delete.

## **Navigating transects**

Key concepts to remember when conducting a survey are outlined below.

1. Do not run the survey as one file. Save the data for individual (preferably straight) survey lines by saving and renaming each line of the surveys individually.
2. While running the transect, avoid over-compensating course corrections, which may occur due to the short lag time between GPS updates and the visual tools on the HDS screen.
  - a. Make subtle changes when off track.
  - b. Allow updates of the screen to occur before making additional adjustments (the external GPS helps here because it updates position five times as quickly as the internal GPS in the HDS unit).
  - c. To avoid over-compensating, select a distant object to steer toward when on track, only occasionally checking position on the HDS.

3. Verify that the screen is “zoomed in” at the appropriate range--this may be all the way in to follow the line. Some operators prefer the ability to see the end point on the screen at all times.
4. Maintain a constant speed when on recording transects. This should be within the range of 2-6 knots.

## Conducting a survey

The following steps should be followed in conducting a survey.

1. Display Sonar and chart pages as a combo page.
  - a. Prior to selecting the active page, adjust the zoom on the chart page to the appropriate scale. Once the Sonar page has been selected as the active page, it will be impossible to adjust the zoom on the chart without switching the active page.
  - b. Use the keypad to select the Sonar page as the first page for the combo display. This is the primary page that can be edited during processing (left side of the screen).
  - c. Select the chart pages from the primary pages combo display list. This is the secondary page (right side of the screen). Press ENTER.
  - d. Pressing the MENU key will open the active panel’s context menu.
  - e. If switching the active page becomes necessary, press and hold the PAGES key down for 1 second.
2. Approximately 50 m prior to beginning the survey, examine the transect line to be sure the vessel has a correct heading given the local conditions.
3. 20 m before the first waypoint, access the Sounder Logging Menus to begin recording:
  - a. Press “Menu.”
  - b. Go to “Log Sonar,” and press Enter.
  - c. Set up the recording session (HDS will reset options if steps are not followed in order).
    - i. Choose save location (Memory card 1 or 2, NOT Internal).
    - ii. Set “Bytes per sounding” to 3200.
    - iii. Select “Log all channels.” This will record the 200-kHz skimmer, and all three channels of the StructureScan transducer (left, right, and down), using the frequency selected in step 22b). An .sl2 file will be generated. It is acceptable to use the default file names offered by the HDS system – SONARxxxx. These file

- names will need to be renamed, using a date/time format as described later, before processing is completed.
- iv. Press Record to begin the recording session.
  - v. WRITE FILENAME, MEMORY CARD NUMBER, AND TIME/DATE IN FIELD BOOK (for use in renaming files).
4. Stop recording by pressing “Stop” twice.
  5. At the end of the recording session, verify that files are present.
    - a. Verify the file has been recorded by performing step 30 (section titled “**Recording**”).
    - b. Go to “Files.”
      - i. Select the memory card number used to store files.
        - 1) Verify file presence.
        - 2) View file if desired (NOTE: Sensitivity parameter on far left of bottom row of buttons may need adjusting before data will appear).
  6. Press Exit twice.
  7. Repeat at the beginning of each transect.
  8. Shutting down: Press “Light/Power.”
  9. Select Power Off and Press Enter.

Various types of data should be manually recorded during a survey for later use. Appendix C contains an example field data sheet that can be copied and used.

## Data file naming convention

Default filenames generated by the HDS have the format SONARxxxx (where xxxx are sequential numbers added by the HDS operating system). This is adequate for field data collection, given that typing in different names on the HSD during data collection can be slow and awkward. However, these files should be renamed after data collection and prior to processing to avoid possibly losing data due to duplicated filenames. All post-processing steps will require filenames in a date/time format:

yyyymmdd\_hhmmss.SL2

Example:



20110612\_133200.SL2  
corresponds to June 12, 2011 at 1:32:00 PM (13:32:00  
is 24-hr time format)

Time and date are not available within the .SL2 files, so the filename is the only means of recording date and time for tidal correction and archival purposes.

## 4 Software Installation and Setup

SAVEWS Jr. Version 1.0 is written in MATLAB and requires the system to have MATLAB R2011b installed or the MATLAB Compiler Runtime (MCR) Version 7.16. SAVEWS Jr. supports only 32-bit and 64-bit Microsoft Windows platforms. The procedures for software installation and setup are outlined below.

1. If MATLAB or the MCR is already installed on the system being used, skip to step 3.
2. SAVEWS Jr. requires the MCR to be installed on computers that are not running MATLAB. Run the MCRInstaller.exe file located on the SAVEWS Jr. distribution disk (***this will require Administrator permissions***). Follow the installation instructions on the screen.
3. Copy the SAVEWS Jr. Program to the folder (directory) of choice. The 32-bit distribution uses the filename SAVEWS\_Jr\_32.exe and the 64-bit distribution uses the filename SAVEWS\_Jr.exe. Note: The phrase “the folder (directory) of choice” means that the executable can be placed anywhere on the computer. But users will need to know where they put it so they can run the program by double-clicking the icon or program name. Most users will choose to put the executable on their desktop and run it from there. Others may separate their work into project directories. If this option is selected, place the executable in a project directory with data files. Either method is acceptable; it is simply a matter of personal preference.
4. If the Finalize Jr. Program is not used, skip to step 8.
5. If the Microsoft .NET Framework 2.0 Service Pack 2 is installed on the system being used, skip to step 7.
6. Install Microsoft .NET Framework 2.0 Service Pack 2. This can be found at the Microsoft Download Center. (<http://www.microsoft.com/en-us/download/details.aspx?id=1639>)
7. Run the Finalize.msi installer (***this will require Administrator permissions***). The installer will walk users through the steps of installing Finalize Jr. on a system.
8. Verify installation and operation of SAVEWS Jr. Copy the test files (20120626\_134202.SL2 and DEFAULT.sjrcfg) from the SAVEWS Jr. distribution and place them in a working folder (directory) of choice.

9. Run the SAVEWS Jr. Program (double-click on the icon or program name) and select the 20120626\_134202.SL2 file as the data input and DEFAULT.sjrcfg as the configuration file.
10. Press the “Process File” button. The program will take several minutes to run and it will generate a 20120626\_134202.jpg file when finished. The 20120626\_134202.jpg file will be in the same folder (directory) as the 20120626\_134202.SL2 file. Graphically compare the 20120626\_134202.jpg file with the VERIFY.jpg file that is in the SAVEWS Jr. distribution. If they appear the same, the program is operating correctly.

Users experiencing difficulty installing this software should contact Eddie Melton at ERDC (601-634-3498).

## 5 Version Notes (Version 1.0)

Version 1.0 is the initial release of the SAVEWS Jr. code. This version uses dual-frequency (200-kHz, and 800-kHz down-looking channel of StructureScan) processing. Training data for this version were obtained from a limited amount of sampling of estuarine eelgrass (*Zostera marina*) in New Jersey and Massachusetts, various freshwater macrophytes (pondweed, milfoil, and others) in Michigan and Wisconsin, and hydrilla in central Florida. This initial version has not been optimized for execution speed and is not capable of running in batch mode, i.e. the user must enter and process one file at a time. As additional environments are sampled and different conditions are encountered, it is anticipated that further modification to the code will be needed, resulting in subsequent versions. Feedback from users is welcomed in identifying shortcomings and getting suggestions on how the code may be improved.

### Processing

The general sequence of steps the user follows in processing data is as follows:

1. Run a single (preferably small, <20 Mb) file with an unturned configuration file (CF).
2. Generate a colorized echogram of the file along with the processed output graphic and ASCII file.
3. Recognize that initial processing will probably not generate satisfactory results, but will help guide the user in modifying the CF to achieve best results.
4. Iteratively change the CF, preferably one variable at a time, until results appear to agree with the colorized echogram.
5. Use the resulting modified CF to process all transects taken in this sampling site.
6. Review each transect to verify that no further modifications to the CF are needed.
7. When all transects have been processed and accepted, run them through a post-processing program (FINALIZE) that concatenates all files, corrects for tides (if necessary) and transducer depth, and converts geographic coordinates (latitude and longitude) to a user-selected Cartesian coordinate system (UTM, state plane, etc).

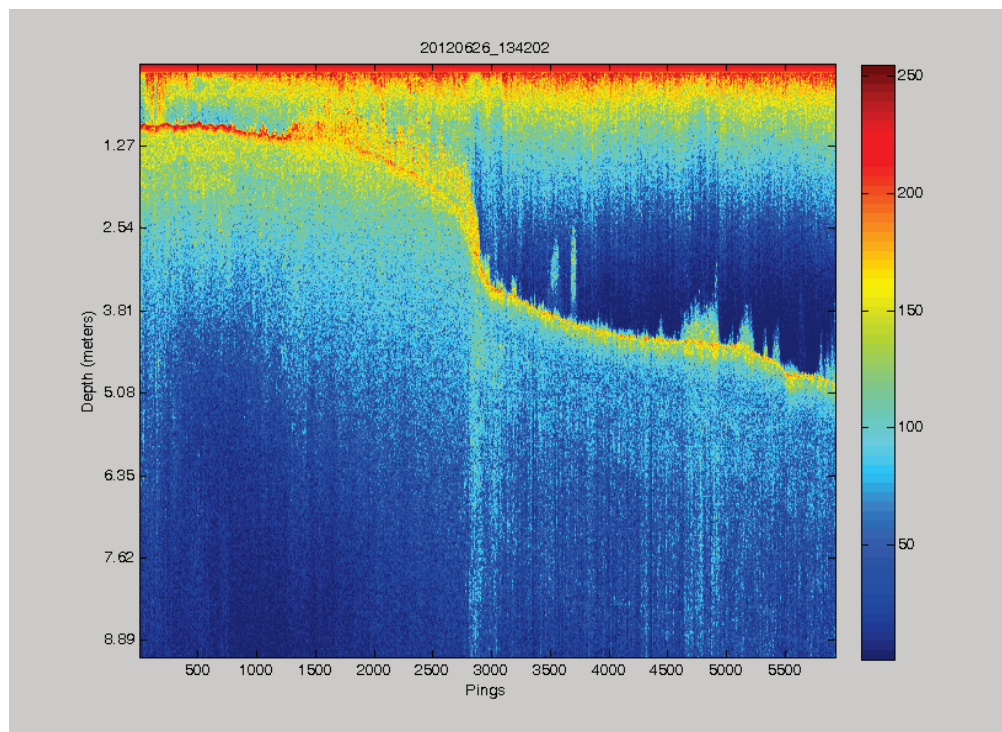
8. Enter the output of FINALIZE into a mapping or statistical analysis package.

In the section that follows, two files are processed to illustrate each of the steps described above.

### **SAVEWS Jr. processor**

The first example file (Figure 14, file 20120626\_134202.SL2, using the required file nomenclature described above) is from Cuttyhunk Harbor, Massachusetts. This file was sampled from high-energy, sand bottom locations near the harbor entrance. The graphic is generated by the processor and represents the 8-bit echo return intensity generated from the downlooking channel of the 800-kHz StructureScan transducer. Hot colors (red and orange) represent high reflectivity (high values) and cool colors (blue and green) represent low reflective “quiet” conditions (low values). The roughly 4-minute recording traversed 440 m, generated 34.6 Mb of data, and almost 6000 pings. The recording began in the shallows (~1-m depth) and ended in the deep (~5-m) area. Along the top edge of the figure is high return generated by transducer residual ringing and surface “noise” (micro bubbles near the surface). Below that, the water column becomes progressively quieter (cool colors) with increasing depth. The sand bottom is revealed as a narrow red/orange line beginning at around 1 m, rapidly getting deeper at around ping 3000, and ending near the 5-m depth. SAV is evident beginning near ping 1300 and extending to around ping 3000 at a depth of approximately 3.5 m (note that depth here is specified as the distance between the transducer face and the bottom, and that the transducer face is submersed at least 0.25 m in the water). In this region, plants (known to be dense eelgrass (*Zostera marina*)) are highly reflective, and the open water above these plants is not very “quiet” before it reaches the near surface noise. Beyond ping 3000, the near bottom waters are very quiet and there are several occurrences of what appear to be low-reflectivity plants (between pings 4700 and 5300). It is unclear whether these are plants, and if so, what species they are. However, they are growing at a considerably deeper depth than the known eelgrass bed, and they exhibit relatively low reflectivity. Figure 14 is actually generated by the first processing of the file described below – this material is covered out of sequence for illustrative purposes.

Figure 14. Colorized echogram of acoustic transect at Cuttyhunk Harbor, MA.



The process begins by initiating the program SAVEWS\_Jr.exe, which produces the main graphic user interface (GUI) window (Figure 15). The user clicks browse and selects an .SL2 file from the subdirectory created to contain the survey data. Next the user clicks **Browse** to select a CF. A separate subdirectory containing just CFs (file type .sjrcfg) is recommended. A generic starter CF is picked for the initial run. These configuration settings are not expected to produce the best output, but obvious errors in the output will help determine which parameters need to be modified. To execute the program, the user then clicks **Process file** (Figure 16). A number of large libraries are read into memory at this point, which may take a minute or two.

When a particular file is run for the first time, the program parses the .SL2 file and reads it into memory while displaying the message *Reading Data File [filename]*. This is a relatively slow process and users are cautioned to be patient. Once this step is complete, the colorized echogram (Figure 14) appears overlain by a series of progress bars (Figure 17) indicating the stage and progress of processing. The sequence of progress bars is as follows: *Computing Thresholds and Extracting Features*, *Finding Biggest Peaks*, *Finding Falling Edges*, and *Determining Canopy Tops*. After reading the data files, the remaining actions occur relatively quickly; if a file is reprocessed, the reading step is skipped.

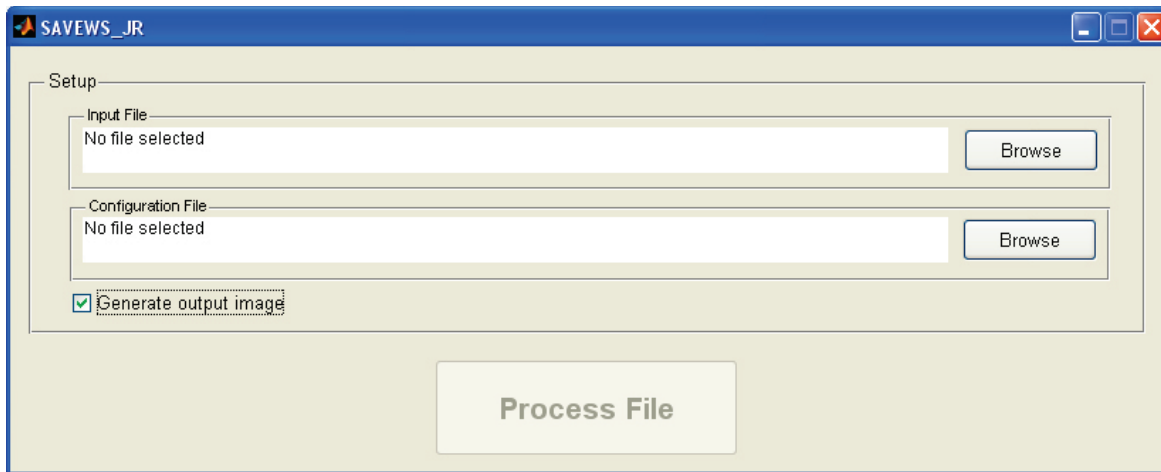
Figure 15. SAVEWS\_Jr data processing window, *Generate output image* is on by default.

Figure 16. Processing GUI filled in and ready to start program.

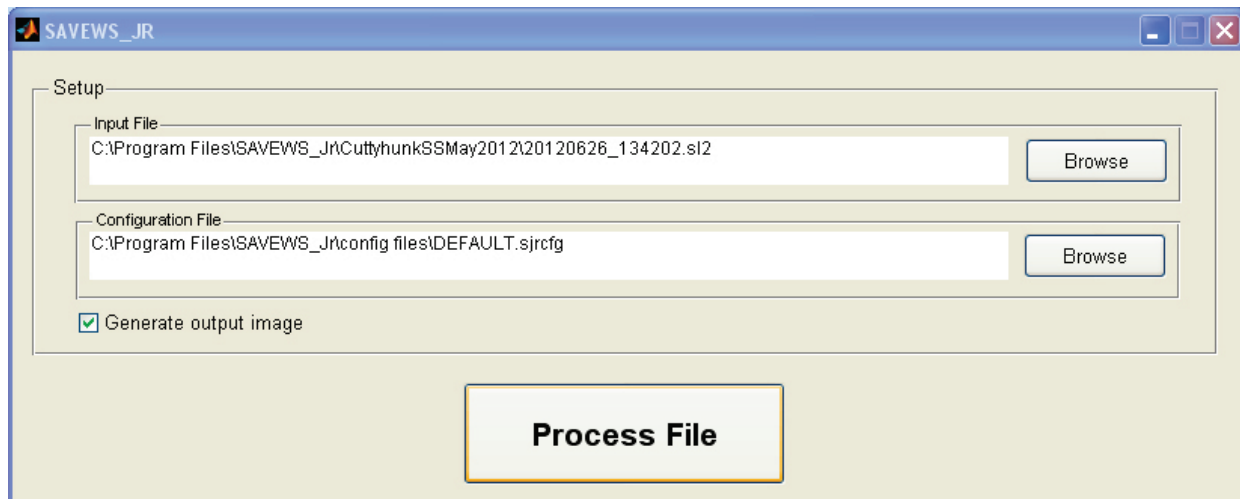
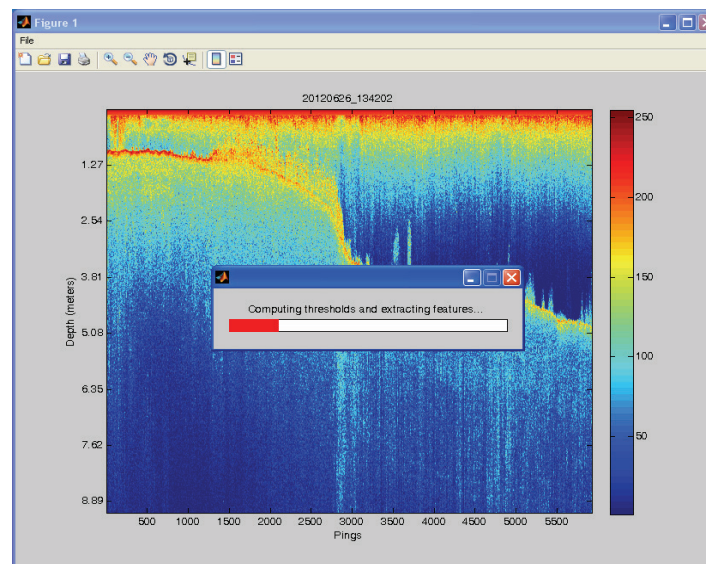


Figure 17. Display during processing.



When processing is complete, three files are placed into the data subdirectory (location of .SL2 files):

1. *filename.\_chart.bmp* – colored echogram of .SL2 file (e.g. Figure 14)
2. *filename.jpg* – graphic of processed output (Figure 18)
3. *filename.sdf* – comma-delimited ASCII file of processed output (Figure 19)

The graphic of processed output (Figure 18) contains three panels. The top panel overlays bottom and mean canopy height declarations onto the colored echogram. The middle panel is a co-aligned data plot of SAV coverage, and the bottom panel is a similarly aligned data plot of mean canopy height. These plots are intended to make it easy for the user to readily evaluate the goodness of the output and to rapidly detect output

Figure 18. Graphic of processed output generated from a non-optimized CF (DEFAULT.sjrcfg).

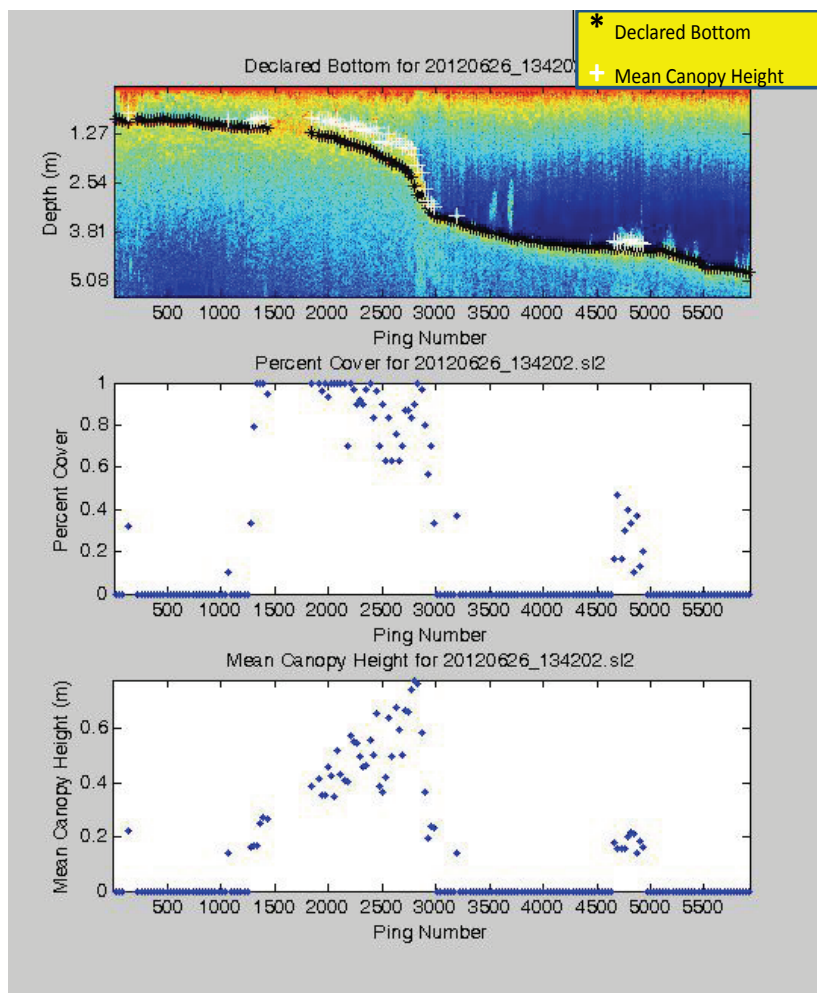




Figure 19. Raw output file (.SDF); a. processing parameters, and b. processed data.

	A	B	C
1	Input Parameters		
2	File Name	20120626_134202.sl2	
3	Date	6/26/2012	
4	Time	13:42:02	
5	Pings Per Report Cycle	30	
6	Mininum Gap for Ping Thresholds (m)	0.1	
7	Noise Threshold	149.1708	
8	Minimum Vegetation Height (m)	0.1	
9	Minimum Vegetation Standard Deviation (m)	0.03	
10	Maximum Vegetation Depth Limit (m)	5	
11	Configuration File used:	DEFAULT.sjrcfg	
12			

a. Processing information from top of .SDF file.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Rpt	Latitude	Longitude	Times(hr)	Day	Month	Year	Center Ping	Bottom(m)	Canopy Height(m)	Percent Cover	Depth to Canopy/Bottom (m)
2	1	41.424656	-70.91875	13.7008	26	6	2012	15	0.883	0	0	0.883
3	2	41.42466	-70.91874	13.7011	26	6	2012	45	0.876	0	0	0.876
4	3	41.424663	-70.91872	13.7013	26	6	2012	75	0.908	0	0	0.908
5	4	41.42467	-70.91869	13.7019	26	6	2012	135	0.946	0.22	32	0.726
6	5	41.424683	-70.91864	13.7027	26	6	2012	225	0.876	0	0	0.876
7	6	41.42469	-70.91863	13.7029	26	6	2012	255	0.876	0	0	0.876
8	7	41.424697	-70.91862	13.7032	26	6	2012	285	0.895	0	0	0.895
9	8	41.424704	-70.9186	13.7034	26	6	2012	315	0.902	0	0	0.902
10	9	41.424711	-70.91858	13.7037	26	6	2012	345	0.902	0	0	0.902
11	10	41.424717	-70.91856	13.704	26	6	2012	375	0.908	0	0	0.908
12	11	41.424724	-70.91855	13.7042	26	6	2012	405	0.889	0	0	0.889
13	12	41.424731	-70.91854	13.7045	26	6	2012	435	0.876	0	0	0.876
14	13	41.424734	-70.91852	13.7048	26	6	2012	465	0.883	0	0	0.883
15	14	41.424738	-70.9185	13.705	26	6	2012	495	0.857	0	0	0.857
16	15	41.424744	-70.91848	13.7053	26	6	2012	525	0.895	0	0	0.895
17	16	41.424748	-70.91846	13.7056	26	6	2012	555	0.902	0	0	0.902
18	17	41.424751	-70.91844	13.7058	26	6	2012	585	0.895	0	0	0.895
19	18	41.424754	-70.91843	13.7061	26	6	2012	615	0.895	0	0	0.895
20	19	41.424758	-70.91841	13.7063	26	6	2012	645	0.914	0	0	0.914
21	20	41.424761	-70.91839	13.7066	26	6	2012	675	0.908	0	0	0.908
22	21	41.424761	-70.91838	13.7069	26	6	2012	705	0.889	0	0	0.889
23	22	41.424765	-70.91836	13.7071	26	6	2012	735	0.914	0	0	0.914
24	23	41.424768	-70.91834	13.7074	26	6	2012	765	0.908	0	0	0.908
25	24	41.424768	-70.91832	13.7077	26	6	2012	795	0.94	0	0	0.94

b. Output data from bottom of .SDF file.

changes with subsequent runs using different configuration inputs. The final output (Figure 19) is a text version of the graphic output (Figure 18) that is used for post-processing or analyses. Variables used in the text output (Figure 19) are defined in Table 2. Before processing another file, the user must close the .SDF file (opened in Excel) or no output will be generated from subsequent runs.

Table 2. Definition of output variables form raw output file (.SDF).

Variable Name	Units	Definition
Report cycle	Integer	Sequential number of output report summarizing N pings
Latitude	Decimal degrees	Geographic coordinates in coordinate system set on GPS (typically NAD83)
Longitude		
Time	Decimal hours	24-hr time parsed from .SL2 filename and incremented with HDS clock time (seconds elapsed since file start)
Day	Integer	Day of month, parsed from .SL2 filename
Month		Month of year, parsed from .SL2 filename
Year		Year, parsed from .SL2 filename
Center ping		Ping number at center location of N-ping report cycle output
Bottom	Meters	Distance between transducer face and algorithm-detected bottom
Canopy height		Mean height of detected plants in report cycle
Acoustic percent cover	Integer	Percentage of valid processed pings in which plants were detected (0..100) (see Appendix D)
Depth to canopy/bottom	Meters	Distance between transducer face and first echo return above USERNOISE (set in configuration file)

Examination of the processed output (Figure 18) reveals that bottom tracking appears reasonable and that much of the eelgrass bed (ping region 1400-3000) has been correctly declared, and some of the apparent sparse vegetation (ping region 4500-5500) has also been detected. An obvious problem is the lack of bottom or plant declarations in dense eelgrass at ping region 1500-1800.

To understand how output problems can be corrected, it is necessary to understand the configuration parameters defined within the CF. A full listing of the CF (DEFAULT.sjrcfg) used to create the first example is shown in Appendix B. Parameters are grouped into *Basic*, *Intermediate*, and *Advanced* categories. The *Basic* group contains parameters that are expected to change routinely. The *Intermediate* group consists of somewhat more advanced parameters; users should have some familiarity with these parameters before changing them. The *Advanced* group consists of parameters that require an in-depth knowledge of the algorithm to manipulate; these parameters generally should not be changed. Users are encouraged to read the description of each parameter in the example CF (Appendix B).

When a file is run for the first time, it is useful to allow the algorithm to automatically pick the **usernoise** parameter value. This is done by setting **usernoise**=0 and **percentile**=75 (Appendix B). The result in the example was that the algorithm picked a **usernoise** value of 149 (line 7, Figure 19a). The key to the missing output is that this region is very “noisy,” i.e. there is not a clearly defined “quiet zone” between the top of the plants and the surface for the **usernoise** threshold selected. As the **usernoise** threshold increases, there will be less sensitivity to water column noise, and also less sensitivity to vegetation detection. By increasing the **usernoise** threshold, users may be able to recover data from the missing region. This can be done by increasing the percentile value, or by manually setting the **usernoise** threshold higher. The second approach was used in the example and the value for **usernoise** was changed from 0 to 160. Improvement in the reprocessed output is evident as shown in Figure 20. While the gap of missing output has been filled in, this action has occurred at the cost of some plant detection sensitivity. A very slight decrease in canopy height and percent coverage in the detected vegetation can be noted. There is an unavoidable tradeoff between noise rejection and detection sensitivity.

A second example was run (Figure 21) to illustrate some other configuration parameters. The selected transect is Eurasian watermilfoil in a northern Wisconsin lake. Several locations along the transect exhibit dense tall vegetation with a noisy water column above. Also, the bottom is not clearly evident at the beginning of the file and in ping region 2300-2500. Processing begins with the starter CF (DEFAULT.sjrcfg, Appendix B) used in the previous example, and Figure 22 is generated. Several problems are immediately evident. Output data are missing from the start of the file (ping region 0-250); apparent false detects are occurring near the end (ping region 2700-3000); and bottom tracking is erratic in ping region 500-750. The automated threshold picker selected **usernoise** = 95.

Two types of problems occur in this scenario—vegetation detection and bottom tracking. The first modification necessary is to correct missing vegetation detections and false detections. The following parameter changes are made to improve vegetation detection performance:

1. Increase the **usernoise value** from 95 to 115. This will reduce sensitivity to water column noise evident in ping region 0-250, and possibly eliminate false detects near the file’s end caused by hypersensitivity of a low threshold.

2. Decrease the **startdepth** value from 0.5 to 0.3 m. The near surface noise is minimal, relative to the previous example. This decrease may help reduce data rejection in ping region 0-250.

Figure 20. Reprocessing file 20120626\_134202 with usernoise=160.

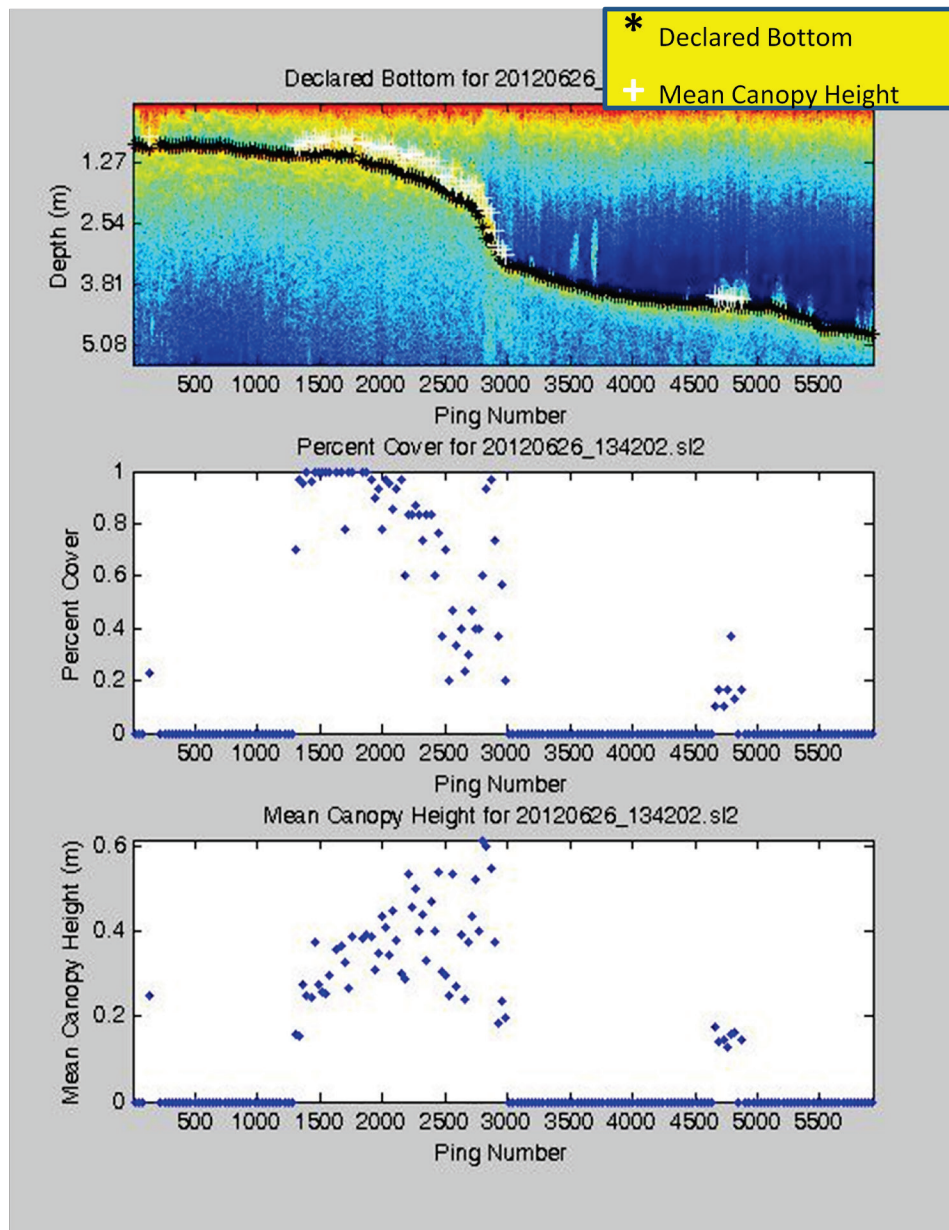
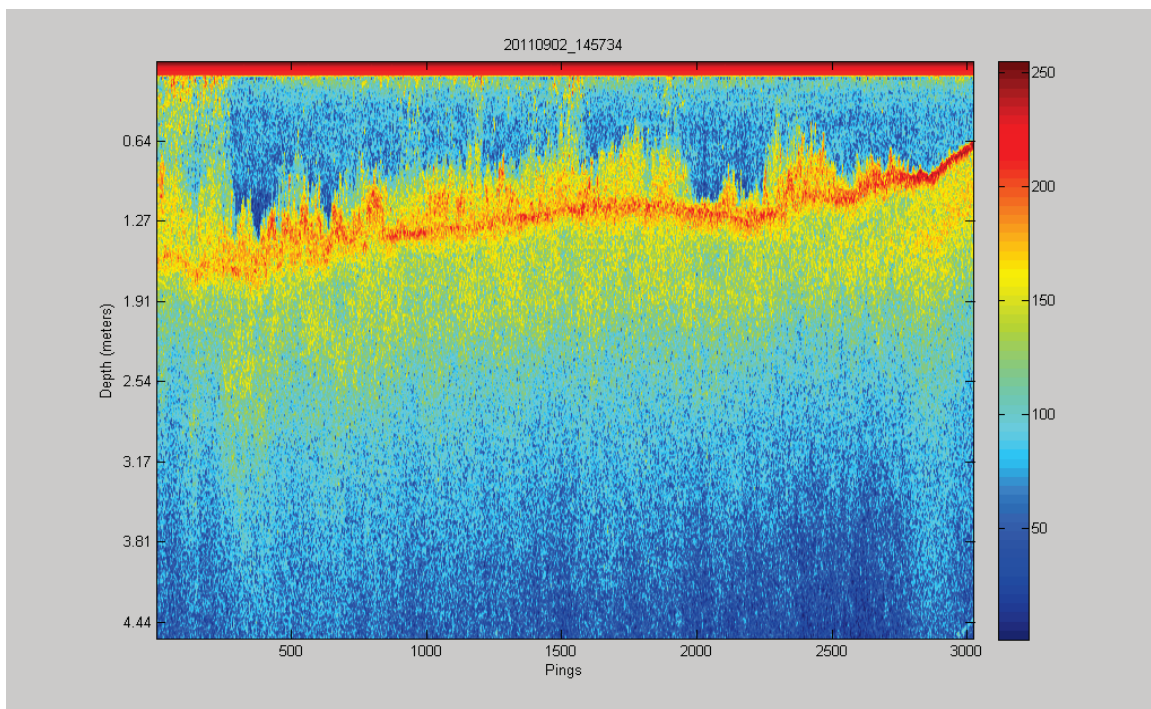


Figure 21. Colorized echogram of acoustic transect of Eurasian watermilfoil in northern Wisconsin.



Output from these modifications is shown below (Figure 23). Reasonable vegetation detections are now being generated from ping region 0-250, and false detections near the end have been eliminated. Bottom tracking in ping region 500-800 is still erratic. A second parameter modification is made to improve bottom tracking:

Set the **bot\_change\_tol** value to 0.10 m (from 10 m). This activates the median filtering of bottom depth declarations. In this case, when the difference between the current bottom depth and the nine-element (**bot\_med\_filt\_size**) median value, centered at the current depth, exceeds 0.10 m, the bottom depth will be reset to the median value. This is more of a cosmetic fix than a true signal processing fix, but it can be handy in some situations.

The reprocessing results (Figure 24) exhibit the desired depth smoothing in ping region 500-800. In this case, the cause of the original erratic bottom depth declarations is unknown – they may have a legitimate physical cause. However, the modification made in the example shows how median filtering can be used to smooth depths, if desired. Median filtering preserves sharp discontinuities in the string of depth estimates – unlike use of a moving average filter. In very dense vegetation, bottom depths frequently become erratic and use of median filtering would be warranted.



Figure 22. Processed output generated from a non-optimized CF (DEFAULT.sjrcfg).

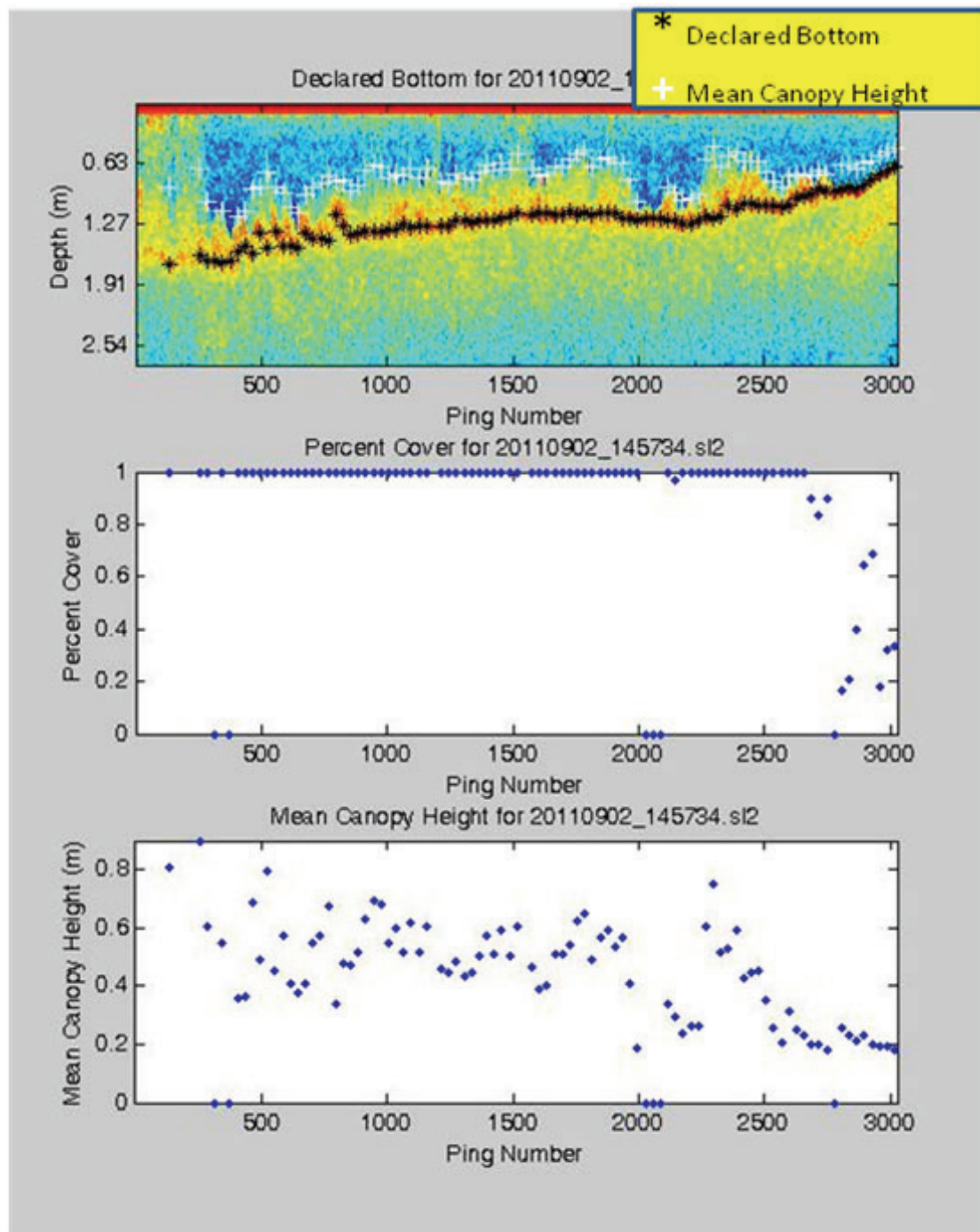


Figure 23. First reprocessing file 20110902\_145734 (usernoise=115, startdepth=0.3) designed to improve vegetation detection performance.

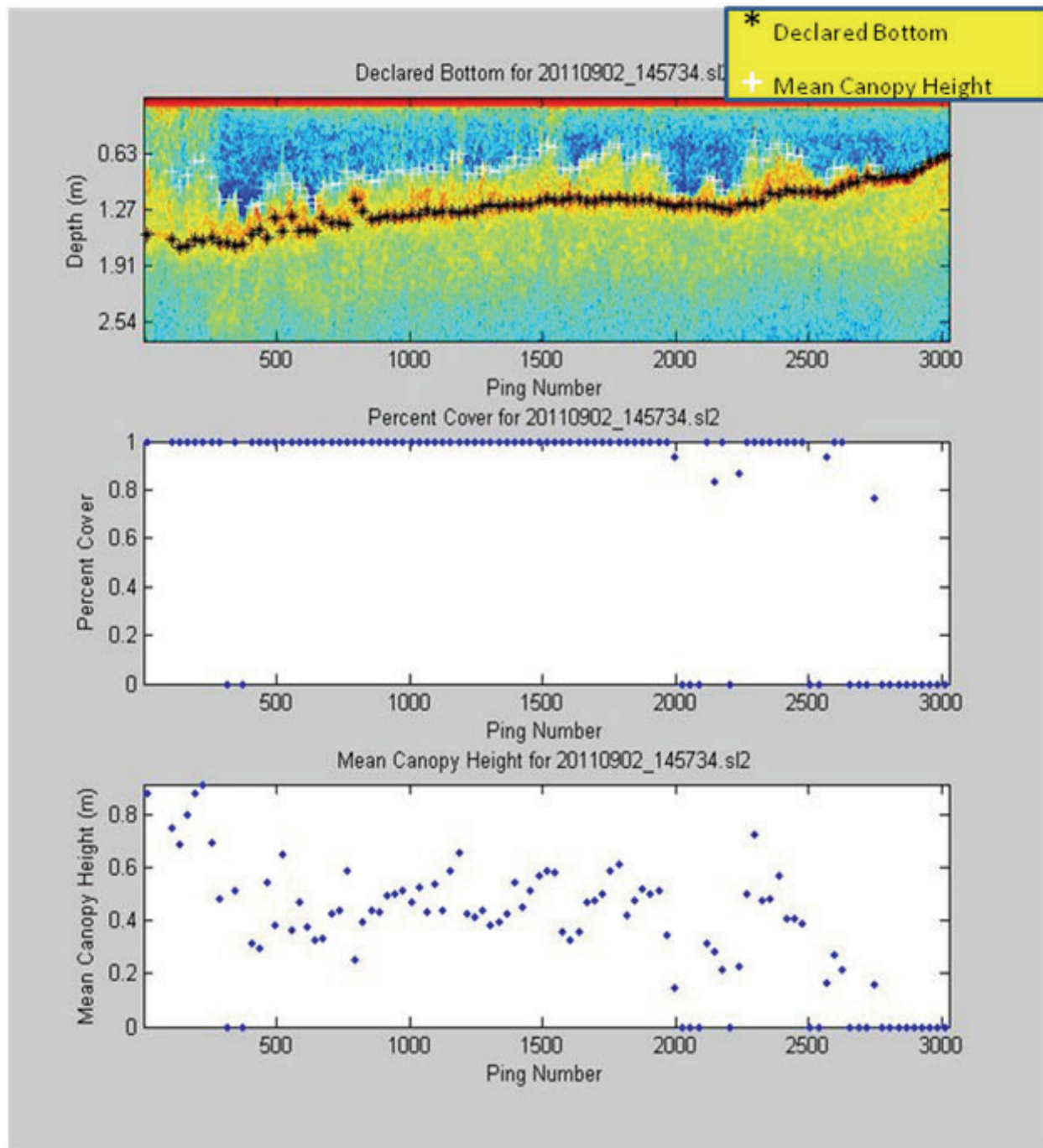
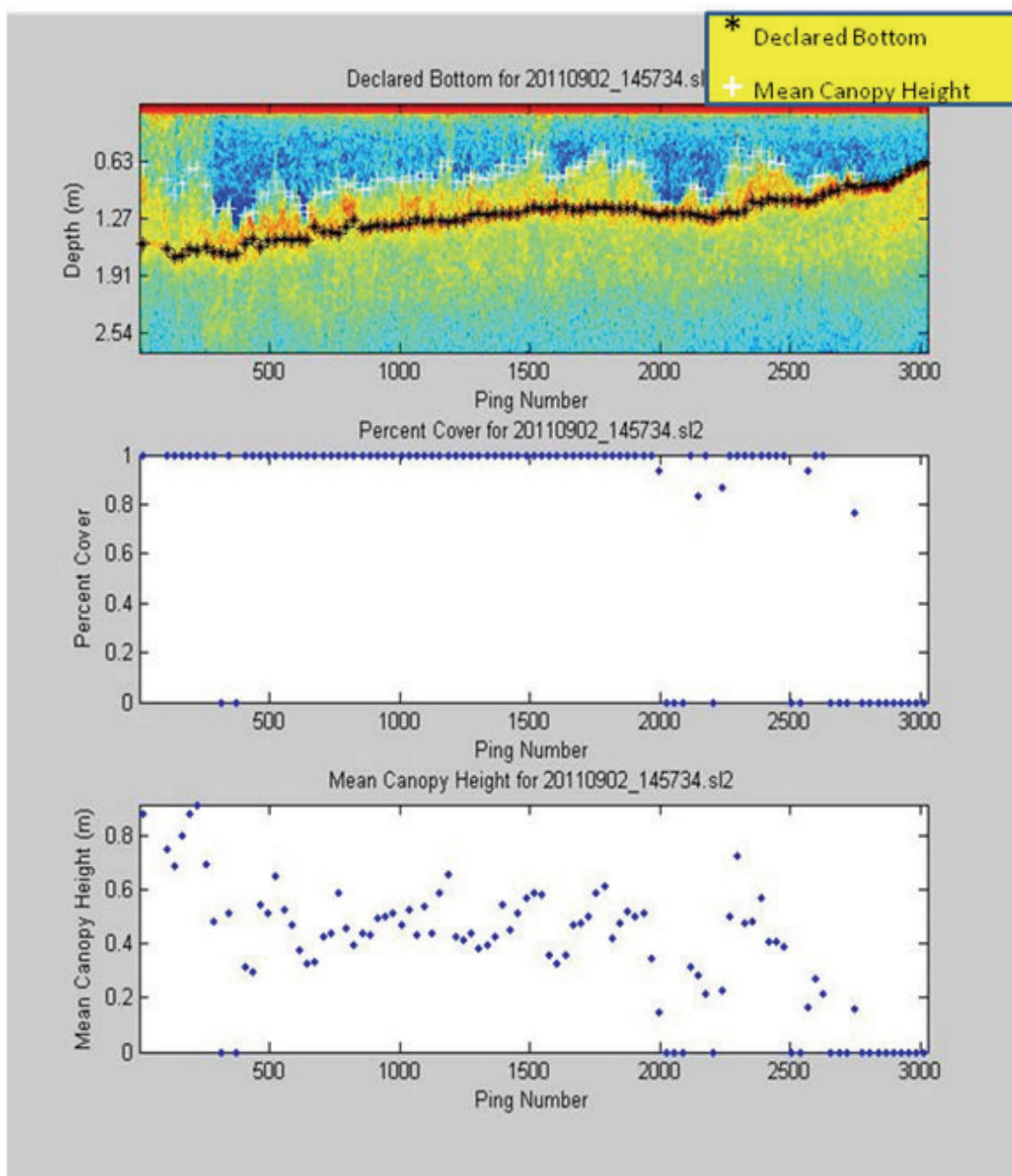


Figure 24. Second reprocessing file 20110902\_145734 (bot\_change\_tol = 0.10m) designed to smooth erratic bottom depth declarations.



The two processing examples above illustrate how the CF can be adjusted to align output of a single file with the user's heuristic interpretation of the echo signal. An acoustic survey typically involves many transects collected from a localized region. Optimizing the CF for each transect in the survey would be unreasonably time-consuming and would lead to inconsistent detection sensitivity among transects. To achieve best performance, users



are advised to select a “typical” and small (<20-Mb) file from within the localized region to iteratively adjust the CF. This optimized CF can then be used to process all other files collected in this region. The user should examine and evaluate the output graphic as a quality control step. If bottom or plant type conditions change significantly over the spatial extent of the surveyed region, it may be necessary to adjust some parameters further.

The above examples began with a generic starting CF (DEFAULT.sjrcfg, Appendix B), which was not optimized for any particular set of environmental conditions. If an application is typically within some specific environment type (eg. Florida hydrilla, coastal eelgrass, etc), users are advised to develop a “customized” starting CF, optimized for specific conditions. This process will save time in arriving at the final CF.

## Post processing

The post-processing program FINALIZE makes depth corrections, coordinates projections to State Plane values, and optionally adds the distance along transects and cross track errors. The individual SDF files are concatenated into a single, comma-delimited ASCII text file ready for entry into a mapping or statistical analysis program. In addition to the SDF files that are to be included, the program requires a data file of tide measurements, a file of SDF filenames, and in some cases, a transect waypoint file. Steps in creating these files and running the FINALIZE program are described below.

1. Tide data file. Figure 25 is an example tide file. This ASCII space-delimited text file can be generated using any text-editing program, such as Microsoft Wordpad or Notepad. The first line is for documentation only. Each subsequent line contains the integer month, integer day of month, time (decimal hours local time, 24 hr), and tide (feet) relative to the selected reference plane. The first data line of the file must contain a tide measurement BEFORE the first recorded SDF file. The last data line must contain a tide measurement

**Figure 25. Tide data file must contain integer month and day, decimal hours local time, and tide (ft).**

```
{tide data: mm,dd,hh.hh,tide (ft)
8 01 11.55 9.4
8 01 11.75 9.3
8 01 11.90 9.2
8 01 12.06 9.0
8 01 12.24 8.9
8 01 12.56 8.6
8 01 12.74 8.2
8 01 12.90 7.9
8 01 13.06 7.6
8 01 13.24 7.2
8 01 13.40 7.0
8 01 13.56 6.5
8 01 13.73 6.1
8 01 13.90 5.6
```

AFTER the last recorded SDF file. If this condition is not met, the program will give a warning message and halt execution. If a tide measurement was not made at the correct time during data collection, it will be necessary to estimate one and enter it.

2. File listing SDF files. Figure 26 is an example file. Each line of the file corresponds to a single SDF file. It is not critical to have this list ordered in any particular way, but it may be convenient to order the files chronologically. The easiest way to generate this file without having to type all the 15-character filenames is to enter the COMMAND PROMPT program (DOS emulator) and type: **dir /B /ON \*.SDF > filelist.txt** from within the proper directory. This will make a list of the 15-character filenames for the SDF files. Users should take care to eliminate any aborted files from the list.

Figure 26. The list file must contain SDF filenames, in date\_time format, transect ID #, depth of transducer face (m), and replicate #.

```
20120801_114000 1 0.20 1
20120801_114400 2 0.20 1
20120801_114900 3 0.20 1
20120801_115600 4 0.20 1
20120801_130300 6 0.20 1
20120801_131100 7 0.20 1
20120801_132000 8 0.20 1
20120801_132600 9 0.20 1
```

3. Waypoint coordinate data file. Computing distance along a transect and cross-track error (error distance off intended path) is an optional feature of FINALIZE, which the user may or may not select. If selected, the user must input a file of waypoint coordinates. An example waypoint coordinate file is contained in Figure 27. This ASCII space-delimited text file can be generated using any text-editing program, such as Microsoft WordPad or Notepad. The first line is for documentation only. Each subsequent line contains the longitude, latitude, transect number, and a point identifier. Note that West

Figure 27. Waypoint file for computing location along transect.

Lon	Lat	Transect	Pt ID
70.35202	43.45018	1	1
70.35355	43.45305	1	2
70.35331	43.45288	2	1
70.35279	43.45133	2	2
70.35245	43.44973	3	1
70.34715	43.4553	3	2
70.3472	43.45551	4	1
70.35296	43.44967	4	2
70.35366	43.44922	6	1
70.34739	43.45547	6	2
70.34773	43.45546	7	1
70.35286	43.4501	7	2
70.35294	43.45037	8	1
70.34794	43.45557	8	2
70.34794	43.45576	9	1
70.35326	43.45003	9	2

- longitude is assumed, therefore making the longitude a positive number. Each transect has two points, a beginning point (1) and an ending point (2). The beginning point represents the starting point for the transect. The ending point represents the end of the transect and should be located closest to the shoreline.
4. Running FINALIZE. Double click on the FINALIZE icon. The SDF FINALIZE window will appear (Figure 28). The user then selects the SDF list, tide data, and output filenames using the browse button (direct typed entry will not work). To include the distance along the transect and the cross track error in the output file, check the Include the Distance Along the Transect and the Cross Track Error box and select the waypoint coordinate file using the browse button. Then select the Datum, State, and the Zone for the State Plane projection. The Zone list is populated based on the selections made in the Datum and State boxes. This computation is embedded in FINALIZE using the commercially available code ProLat.dll, version 3.01, by Effective Objects (<http://www.effectiveobjects.com>), which uses USGS computational methods. If the combination of Datum, State, and Zone do not correctly match, Zone will appear in the selection box and users will not be able to initiate the program. In these cases, clicking **Create Output File of Corrected Data** will initiate the program. If invalid data have been entered, the button will be deactivated until correct data have been entered. Status of the program, including any errors, will be noted within the **Program Status** window.
  5. Output file format. The output is in an ASCII comma-delimited (.CSV) format. Figure 29 is an example. Table 3 defines variables contained in this file.
  6. Further processing. Some users may find it useful to generate additional summary variables based on the outputs provided. One such variable is Biovolume. This is defined as the portion (percentage) of the water column occupied by vegetation and is computed as:

$$\text{Biovolume} = \text{acoustic\_percent\_cover} * \text{Height\_m} / \text{Depth\_bottom}$$

Figure 28. FINALIZE graphic user interface window after executing program.

**SDF FINALIZE**

ODF List Filename  
C:\Program Files\SAVEWS\_Jr\Bidderford\_080112\filelist.txt Browse

Tide Data Filename  
C:\Program Files\SAVEWS\_Jr\Bidderford\_080112\tide.txt Browse

☐ Include the Distance Along the Transect and the Cross Track Error

Waypoint Coordinate Filename  
Browse

Output Filename  
C:\Program Files\SAVEWS\_Jr\Bidderford\_080112\Output.csv Browse

Program Status

- 20120801\_114400
- 20120801\_114900
- 20120801\_115600
- 20120801\_130300
- 20120801\_131100
- 20120801\_132000
- 20120801\_132600
- Processing Complete

State Plane Zone

NAD83 Maine West (1802)

Create Output File of Corrected Data

Exit

Figure 29. Example output of FINALIZE program (Output.CSV).

Lon	Lat	X_stpIn	Y_stpIn	Year	Day	Time	Trans	Depth_Bottom	Depth_Canopy	Cover	Height_m
70.35202	43.45018	2903529	224880	2012	214	11.6671	1	-3.93	-3.5	66.67	0.43
70.35203	43.45021	2903526	224889	2012	214	11.6675	1	-4.79	-4.16	73.33	0.63
70.35204	43.45023	2903524	224898	2012	214	11.6679	1	-5.42	-5.42	0	0
70.35205	43.45026	2903521	224907	2012	214	11.6684	1	-5.51	-5.51	0	0
70.35206	43.45029	2903519	224918	2012	214	11.6688	1	-5.5	-5.5	0	0
70.35207	43.45032	2903517	224929	2012	214	11.6693	1	-5.52	-5.23	13.33	0.29
70.35208	43.45035	2903514	224940	2012	214	11.6698	1	-5.39	-5.39	0	0
70.35209	43.45038	2903512	224950	2012	214	11.6702	1	-5.33	-5.33	0	0
70.35209	43.4504	2903510	224960	2012	214	11.6707	1	-5.32	-5.32	0	0
70.35211	43.45043	2903506	224971	2012	214	11.6711	1	-5.3	-5.3	0	0
70.35212	43.45046	2903502	224981	2012	214	11.6716	1	-5.15	-5.15	0	0
70.35213	43.45049	2903499	224991	2012	214	11.672	1	-5.13	-5.13	0	0
70.35215	43.45051	2903495	225001	2012	214	11.6724	1	-5.08	-5.08	0	0
70.35216	43.45054	2903492	225009	2012	214	11.6729	1	-5.04	-5.04	0	0
70.35218	43.45056	2903488	225018	2012	214	11.6733	1	-4.86	-4.86	0	0
70.35219	43.45059	2903485	225027	2012	214	11.6737	1	-4.75	-4.75	0	0
70.3522	43.45061	2903481	225036	2012	214	11.6741	1	-4.71	-4.71	0	0
70.35221	43.45063	2903479	225045	2012	214	11.6745	1	-4.59	-4.59	0	0
70.35222	43.45066	2903475	225053	2012	214	11.6749	1	-4.43	-4.59	0	0
70.35224	43.45068	2903472	225063	2012	214	11.6754	1	-4.21	-4.21	0	0
70.35225	43.45071	2903468	225072	2012	214	11.6758	1	-4.04	-4.04	0	0
70.35227	43.45073	2903464	225080	2012	214	11.6762	1	-3.96	-3.96	0	0
70.35228	43.45076	2903461	225090	2012	214	11.6766	1	-3.89	-3.4	20	0.49
70.35229	43.45078	2903457	225098	2012	214	11.677	1	-3.81	-3.41	40	0.4
70.35231	43.45081	2903454	225108	2012	214	11.6774	1	-3.8	-3.38	93.33	0.42

Table 3. Definition of output variables from FINALIZE program.

Variable name	Units	Definition
Lon	decimal degrees	Geographic coordinates in selected datum
Lat		
X-stpIn	feet	Easting in state plane coordinates
Y-stpIn		Northing in state plant coordinates
Year	integer	4-digit year
Day		3-digit day of year
Time	hours	Local time, 24-hr clock
Transect	integer	Transect number
Depth_Bottom	meters	Distance between water surface and detected bottom (corrected for transducer depth and tides)
Depth_Canopy_Bottom		Distance between water surface and first object (contiguous with detected bottom) above threshold ( <b>usernoise</b> )
Acoustic_Percent_Cover	percent	Estimated coverage, computed as percentage of pings in reporting cycle in which plants were detected (see Appendix D)
Height_m	meters	Average estimated plant height in pings detected with plants in reporting cycle

## 6 Caveats and Limitations

The authors are currently aware of a number of performance limitations associated with Version 1.0 processing under certain conditions. These known limitations and associated caveats are listed below.

1. **Soft, highly absorptive bottom.** When a very light bottom, such as floc, or very light organic mud is encountered, the acoustic pulse may be absorbed instead of reflected. When this occurs, no bottom detection will be registered by the algorithm. If SAV is present, the top of the canopy will probably register as the bottom, but SAV will not be declared present. There is currently no approach to handle this situation.
2. **Short/low-density SAV.** The detection limit for Version 1.0 has not yet been quantitatively established. This is expected to occur as additional ground-truthed data become available. Experience with the original version of SAVEWS showed that detections fell to zero as SAV became shorter and sparser. The computed detection limit for this system was a height of 7 cm and a density of  $60 \text{ g m}^{-2}$  (wet weight). Sparse beds of *Halodule wrightii* were frequently encountered below this detection limit. It is expected that the detection limits for SAVEWS Jr. may be similar.
3. **Acoustically impenetrable canopy.** When a submerged canopy is so dense that all acoustic energy is reflected from it, no energy is left to reflect from the bottom. When this occurs for many adjoining pings, the top of the canopy will probably be declared to be the bottom and SAV will either not be detected at all or will be mischaracterized. This situation has been observed with very dense Eurasian watermilfoil canopies that form below the surface. These can become colonized with filamentous algae that trap gas, further increasing the acoustic reflectivity of the canopy top. The use of dual frequencies within the current code greatly reduces this occurrence; however, it will still occur under very dense canopy conditions. A solution for this situation is being worked on that involves subtracting a bathymetric grid from the top-of-canopy depth grid generated by acoustic mapping. Significant differences in depth would indicate the presence of plants. The bathymetric grid may be obtained from a separate data source, or it may be generated by acoustic mapping during a period of minimum SAV biomass.
4. **Species discrimination.** The algorithm generates data that characterized SAV canopy geometry. There is currently no general

capability to discriminate SAV species or even general classes of SAV. There are, however, a number of specific conditions when limited discrimination is possible. When species present in a body of water are known and there are large differences in characteristics measured by the acoustic system (height for instance), then discrimination is possible. A height discriminator was used to demonstrate the ability to differentiate eelgrass (*Zostera marina*) from marine macroalgae in a New England estuary during summer.<sup>1</sup>

5. **Debris in bottom.** The signal processor detects SAV by looking for a contiguous signal above and connected to the bottom. Many things other than SAV can cause such a signal. Sunken debris, branches, and drowned trees can generate an acoustic signal that is indistinguishable from SAV. The proper way of assessing the accuracy of the processor output is with a statistically sound ground-truth sampling effort, which is not covered in this document. One means of mitigating false SAV detections due to debris is to set the **maxplantdepth** variable in the configuration file to the observed maximum depth of plant growth. This will disallow detection of plant-like signatures at depths too deep to be plants.
6. **Rocky irregular bottom.** The bottom tracker within the algorithm makes the assumption that the depth of the true bottom changes very little between adjoining pings. This is true for virtually all sediment bottoms. When the bottom consists of large rocks and cobbles, it becomes irregular and this assumption is violated, resulting in incorrect bottom tracking. A separate algorithm is being developed to handle this situation; it will be incorporated into a subsequent version of SAVEWS Jr.
7. **Boat wakes and choppy water.** Boat propellers, breaking waves, and choppy water act to incorporate small bubbles into the water column. These bubbles are very reflective acoustically and can exceed thresholds used within the algorithm (**usernoise**). This can lead to false or missed SAV detections. It is best to avoid boat wakes (particularly your own) when executing survey transects, and if conditions get too choppy, it is best to suspend operations until calmer conditions occur.
8. **Topped vegetation.** The software is designed to detect bottom-attached vegetation that has not reached the surface. The algorithm looks for a zone of “quiet water” with echo intensity below **usernoise** that is at least **mingap** meters in depth between **startdepth** and the first detected returns above **usernoise**. If this condition is not found, the ping data are

---

<sup>1</sup> Sabol, B. E. Lord, K. Reine, and D. Shafer. 2008. Comparison of acoustic and aerial photographic methods for quantifying the distribution of submersed aquatic vegetation in Sagamore Creek, NH, report ERDC TN-DOER-E23. U. S. Army Engineer Research and Development Center, Vicksburg, MS.

declared to be noisy (i.e. bad) and not output. If the percentage of pings in a report cycle is below the **required\_good value**, then output of that report cycle is suppressed. If working in near-topped vegetation, careful setting of these parameters may allow the output of some or all of these ping samples.

9. **Final caveat – VERIFY OUTPUT.** If the software described here declares that vegetation of a certain density and height is detected, this only indicates that the acoustic returns are consistent with a scenario where the unknown source of the echoes is submersed vegetation of that particular density and height. Conversely, if output declares a location to be unvegetated, this is only an indication that no signals consistent with submersed vegetation were detected. Vegetation may be present, but at a level below the detection limit of the echo sounder, or at a level below the detection settings of the configuration file. Output should always be verified with at least a limited ground truth sampling or observation effort.



## 7 Point of Contact

The authors appreciate and welcome feedback and comments from users that will help to identify needed improvements to the code. Point of contact is as follows:

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To send files over 8 Mb in size, please use the AMRDEC/SAFE utility:  
(<https://safe.amrdec.army.mil/SAFE2/>).

## References

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## **Appendix A: Assembling a Self-Contained SAVEWS Jr. Field Unit**

This appendix describes the parts necessary to construct a portable, self-contained SAVEWS Jr. system. The system described in this section is an example of a functioning and tested system used by the New England District of USACE. Please note that damage to the Lowrance HDS system or LSS2 StructureScan unit resulting from modification of factory components or incorrect wiring procedures is the responsibility of the user. The Lowrance factory wiring diagram provided with the HDS system and appropriate in-line fuses should be used in assembly of the system.

The system (Figure A1) consists of a Lowrance LSS-2 structure scan module and a 12-V DC power source housed in a waterproof case (Figure A2), a quick disconnect swivel mount for the HDS unit, and a waterproof through-deck fitting for transducer and power connections (Figure A3). The system includes provisions for external power through the use of a 12-V water-resistant male trolling motor socket built into the case (Figure A4), which is paired with female trolling motor plug-wired ring terminals to receive power from an external 12-V battery. The pictured system also includes a male serial connector wired to the NMEA output on the HDS power/data cable. The transducers (455/800-KHz StructureScan and 200-kHz skimmer) and external GPS antenna are mounted to an adjustable bracket (Figures A5 and A6), which clamps on to the bow or rail of the survey vessel. The external GPS antenna (not pictured) should be mounted to a pole that can be clamped to the transducer bracket. This allows the user to overlay position data on a paired video system recording in real time or to another external source. A parts list for the example system is provided in Table A1.

Figure A1. Portable SAVEWS Jr. System.



Figure A2. LSS-2, 12-V power source and wiring.

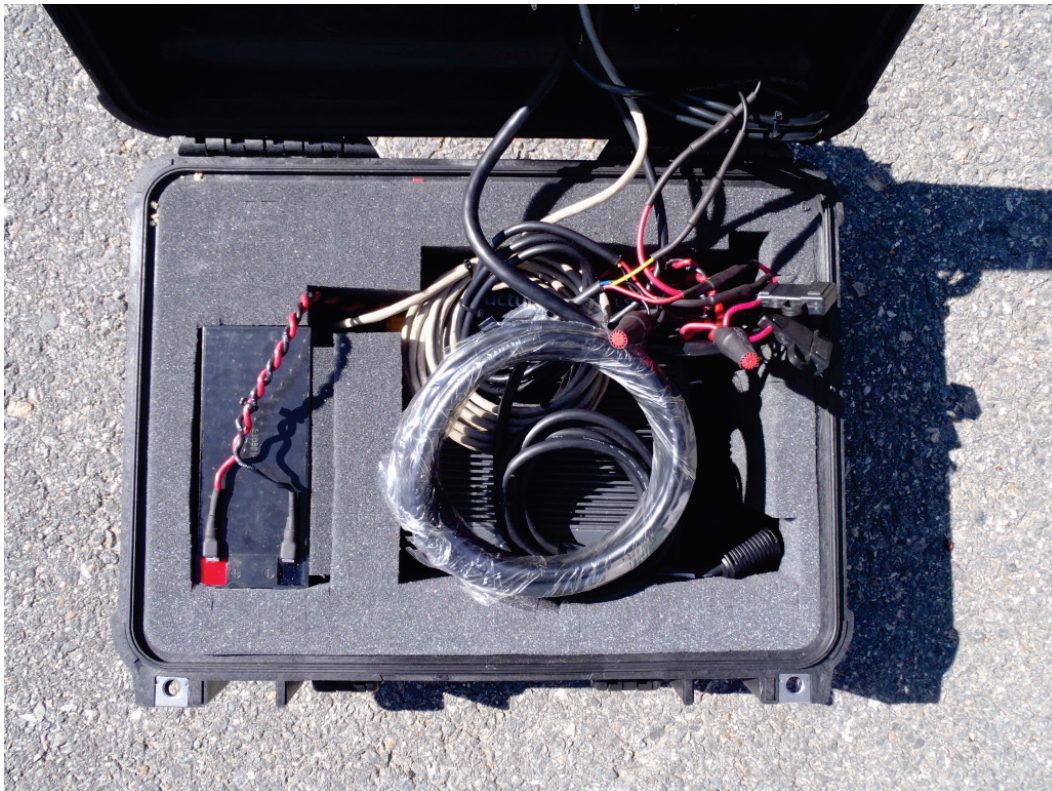




Figure A3. Quick disconnect mount external connections.



Figure A4. External power connection.



Figure A5. Transducers, mounted on pivot arm, and GPS antenna mounting bracket.



Figure A6. Transducer and GPS bracket in use.

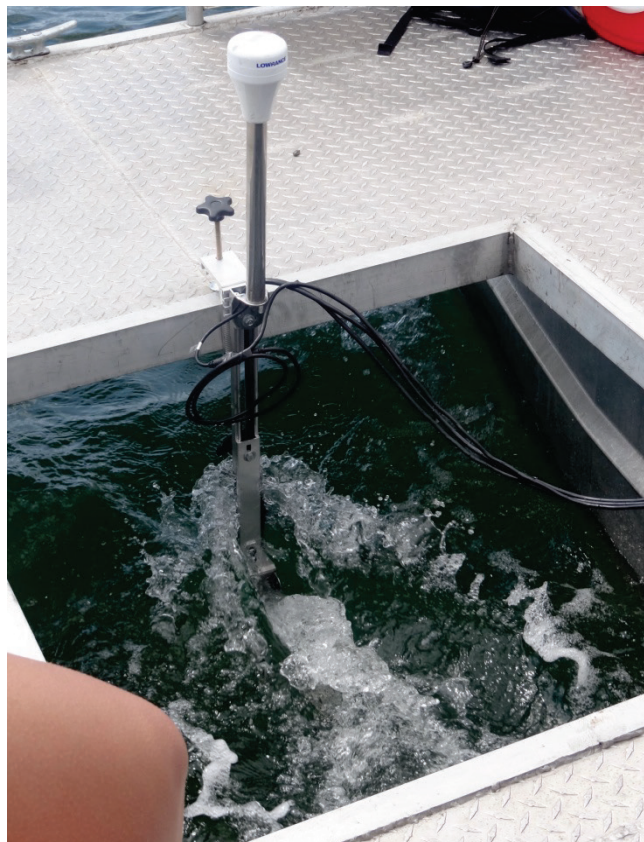




Table A1. Components of example self-contained SAVEWS Jr. system

Component	Description	Part #
Integrated echo sounder with internal GPS system	Lowrance HDS-10 with 50/200kHz skimmer transducer	Lowrance 000-0140-02
Structure Scan module and transducer	Lowrance LSS-2 Structure Scan module for HDS systems with 455/800 kHz transducer	Lowrance 000-0132-06
Structure Scan transducer extension cable	Lowrance extension cable for LSS-2 transducer	Lowrance 99-006
External GPS	Lowrance LGC-4000 high sensitivity GPS receiver antenna	Lowrance 000-0125-28
NMEA 2000 network	Lowrance NMEA 2000 network	N2K-EXP-RD-2
Waterproof case	Pelican Case 1450 with Pick 'N Pluck Foam Case	Pelican 1450
Removable mount for HDS unit	Johnny Ray swivel mount for electronic instruments with push-button release	Jonny Ray JR-300
Waterproof through-deck fitting	Large CableClam waterproof fitting	Blue Sea Systems 1003
Adjustable transducer mounting bracket	Sully transducer mounting bracket for pontoon and thick-transom boats (selected for versatility)	Sully 8001P
Internal power source	12-V/7.5-Amp rechargeable battery	NA
Optional 12-V external power connection	12-V 2-wire trolling motor connectors -male boat side socket (case) -female plug (wire with ring terminals or alligator clips to external battery)	Sierra WH10520 (male) WH10530 (female)
Power switch for running the HDS unit without the LSS-1 module	Chrome-plated 12-V DC SPST toggle switch with water-resistant switch boot	NA

\*\*\*\*\*

For questions, please contact:

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\*\*\*\*\*

## Appendix B: Configuration File -DEFAULT.sjrcfg

Configuration file testing in May 2012; Cutty Hunk data collected by Ben Loyd; file created 07/19/12

The values for the parameters in this file may be edited.

WARNING! CHANGING ANYTHING OTHER THAN THE NUMERIC VALUES FOR THE PARAMETERS WILL CAUSE THE CONFIGURATION FILE TO BECOME INVALID!

\*\*\*\*\*

Basic Parameters - change as needed

\*\*\*\*\*

n	30	The number of StructureScan pings used per report cycle. Structure-Scan operated as a fixed rate of 30 Hz.
heightmin	0.10	Minimum plant height (m) (distance between declared bottom and shallowest above-threshold signal) required for a candidate plant detection declaration.
stdmin	0.03	Standard deviation (m) of difference between plant height of adjoining pings. Both STDMIN and HEIGHTMIN must exceed this minimum for a declared plant detection (AND function). To use only one feature, set the other to zero.
maxplantdepth	5	The maximum bottom depth (m), uncorrected for transducer depth or tides, at which plants are found. This eliminates any candidate detection below this depth, and output is declared unvegetated.



\*\*\*\*\*

#### Intermediate Parameters - change with caution

\*\*\*\*\*

startdepth	0.5	The depth (m) below transducer (zero depth) to start processing. This value can be set higher if it is necessary to read past an interference such as reflection from the motor's lower unit. All data prior to this depth are ignored.
usernoise	0	Setting this value to zero will activate automated determination of the noise threshold using the percentile value below. If set to a non-zero value, that number will be used as the noise threshold value.
percentile	75	The percentile of program-generated noise threshold data to be represented by the program-determined overall noise threshold. Higher percentile values result in higher thresholds, with less sensitivity to noise and plant detection.
mingap	0.10	The minimum quiet zone distance (m) that must be below the noise threshold in order to detect vegetation. If this quiet zone minimum is not met, the ping is rejected as bad data. Only decrease this value below 0.10 m if working in extremely shallow water or inherently "noisy" water. In this situation, an alternate approach would be to increase the <b>usernoise</b> value.
bot_med_filt_size	9	Parameter for smoothing bottom declarations. The value represents the number of elements used in a median filter. Use only odd numbers between 5 and 13.
bot_change_tol	10	Parameter for smoothing bottom declarations. If deviation (m) between current value and the median determined by median filter of size. <b>bot_med_filt_size</b> exceeds this value, then the current value will be replaced by the median. Deactivate this feature by setting it to a very large value, such as 10 m.

cand_veg_amt	5	The minimum percentage of pings in a report cycle that must be candidate vegetation before output is declared to be vegetation. If this percentage is not met, the report is declared unvegetated.
required_good	30	Minimum percentage of pings in report cycle (set as n above) that must be valid data before that report cycle is output (30 is considered the minimum recommended value).

\*\*\*\*\*

#### Advanced Parameters - recommend not changing

\*\*\*\*\*

swin	9	The width of the median filter to be used in smoothing the pings. If changing this parameter, refer to filterflag in the "Intermediate Parameters" section to complete parameter setup.
th_limit	230	The maximum allowable noise threshold for a ping.
use_all	1	Set this value to 1 for all data to be used, or 0 for only half of the data (depth-wise) to be used. This is a data reduction option that achieves processing time cost savings if the depth recording value is > 2x bottom depth.
hist_width	0.02	The width (m) of the bins to use in the histogram analysis that results in bottom declarations. This value represents the bin widths into which bottom candidates are placed in order to make accurate bottom declarations.
bot_wid_percent	1	The percentage of bottom widths that can have a width of 0. This is used to set the threshold value to calculate the width of the bottom. The threshold value is increased until <b>(bot_wid_percent)</b> percent of pings have no bottom width.
filterflag	0	Set this value to 1 if median filtering of the original ping data is desired, or 0 if median filtering is NOT desired. For 200-khz input data, this filtering must always be used. If using median

filtering, refer to "swin" in the "Advanced Parameters" section.

\*\*\*\*\*

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If sending files to troubleshoot, always send the .SJRCFG file used.

\*\*\*\*\*

## **Appendix C: Suggested Field Datasheet**

Date \_\_\_\_\_

Vessel\_\_\_\_\_

Location \_\_\_\_\_

Crew \_\_\_\_\_

Operator\_\_\_\_\_

Transducer mount location\_\_\_\_\_

Tide data source\_\_\_\_\_

Transducer depth (m)\_\_\_\_\_

Equipment ID # \_\_\_\_\_

[illegible]

## Appendix D: Description of Acoustic Percent Coverage

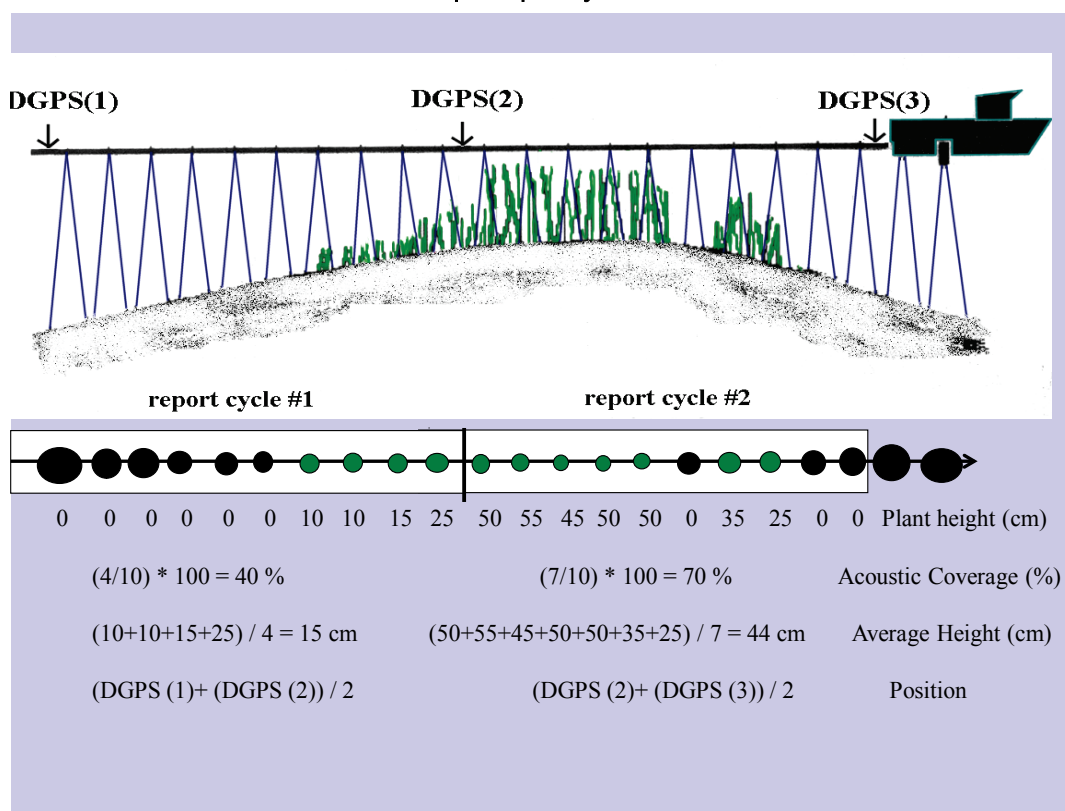
Percent coverage is a widely used quantitative metric to characterize plant stands, both terrestrial and aquatic. Measurements of plant percent cover may be more ecologically meaningful than numbers of individuals, since cover is likely to provide a better measure of plant biomass than abundance (Mueller-Dombois and Ellenberg 1974). Visual estimates of seagrass percent cover using quadrats has been shown to require fewer replicates and less sampling effort for detecting differences than estimates of shoot count or biomass, making percent cover estimates more cost effective (Heidelbaugh and Nelson 1991). However, it is not practical to sample large areas using this technique. Alternatively, underwater videography has also been used to estimate seagrass basal area coverage over larger areas, but these methods are limited to areas with good water clarity (Norris et al. 1997). Both quadrat and underwater videography methods involve imposing a frame of a known size over the bottom, followed by estimating the proportion of the surface area within the frame that is occupied by vegetation.

In some ways, the acoustic technique presented here is analogous to a series of visual estimates of percent cover. For example, each individual sample (single ping) of the SAVEWS Jr. system could be likened to a small quadrat; SAVEWS Jr. transects would thus be similar to a series of contiguous small quadrats arranged in a belt transect. In this case, overall seagrass cover within the area occupied by the belt transect would be computed as the average cover of all quadrats within that transect, and as pointed out by Mueller-Dombois and Ellenberg (1974), continuous transects of evenly spaced points should result in more accurate estimates of plant cover than random placements of grouped points. However, the way in which seagrass cover is detected and estimated in the hydroacoustic technique is fundamentally different. In the visual methods, the percent cover of seagrass within each quadrat is estimated as the proportion of the bottom that is covered by vegetation. In contrast, the acoustic technique classifies each individual sample (single ping) as either detecting or not detecting SAV. The requirement for detection is that acoustically reflective material occurs contiguously above the bottom for some minimum distance. As noted in this manual, the sensitivity of the acoustic echo and

minimum distance above the bottom required for detection can both be set by the user to be more or less sensitive, based on conditions and survey objectives. Coverage is then estimated as the percentage of pings within a localized area (settable as a reporting cycle using parameter  $N$  in CF, see Appendix B). Each ping within the reporting cycle either represents a detection or it does not (binary). While this seems a reasonable approach given the constraints of the acoustic system, it is a fundamentally different measure from the physical and visual measured. For this reason, this measure has been labeled as *Acoustic Percent Coverage*. The resulting acoustic percent coverage summarizes results from a linear string of binary detection samples.

This is illustrated below, along with an example of the calculations for coverage and mean height (Figure D1).

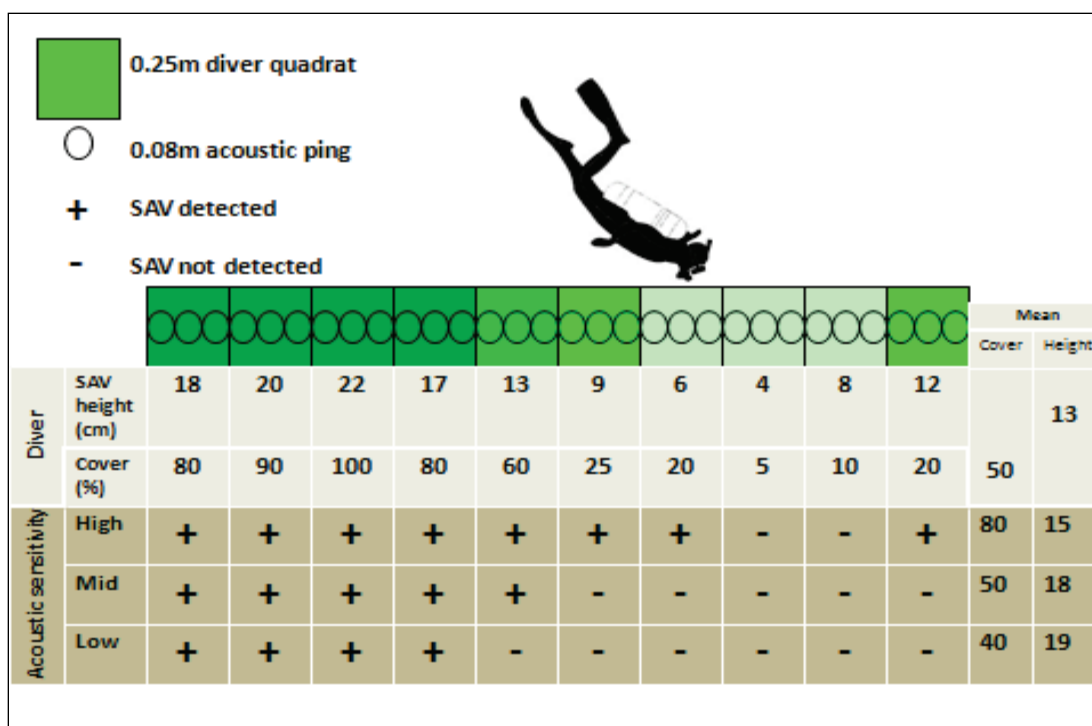
Figure D1. Acoustic survey cartoon and computation of outputs using 10 pings per report cycle.



The flexibility in setting processing parameters, the binary nature of detection, and the fact that there will always be an inherent (and variable) detection limit makes acoustic coverage different from the standard coverage measure. This is illustrated in the hypothetical example below

1. Highest sensitivity: plant height>5 cm **and** coverage>15%;
2. Intermediate sensitivity: plant height>10 cm **and** coverage>20%;
3. Lowest sensitivity: plant height>15 cm **and** coverage>25%.

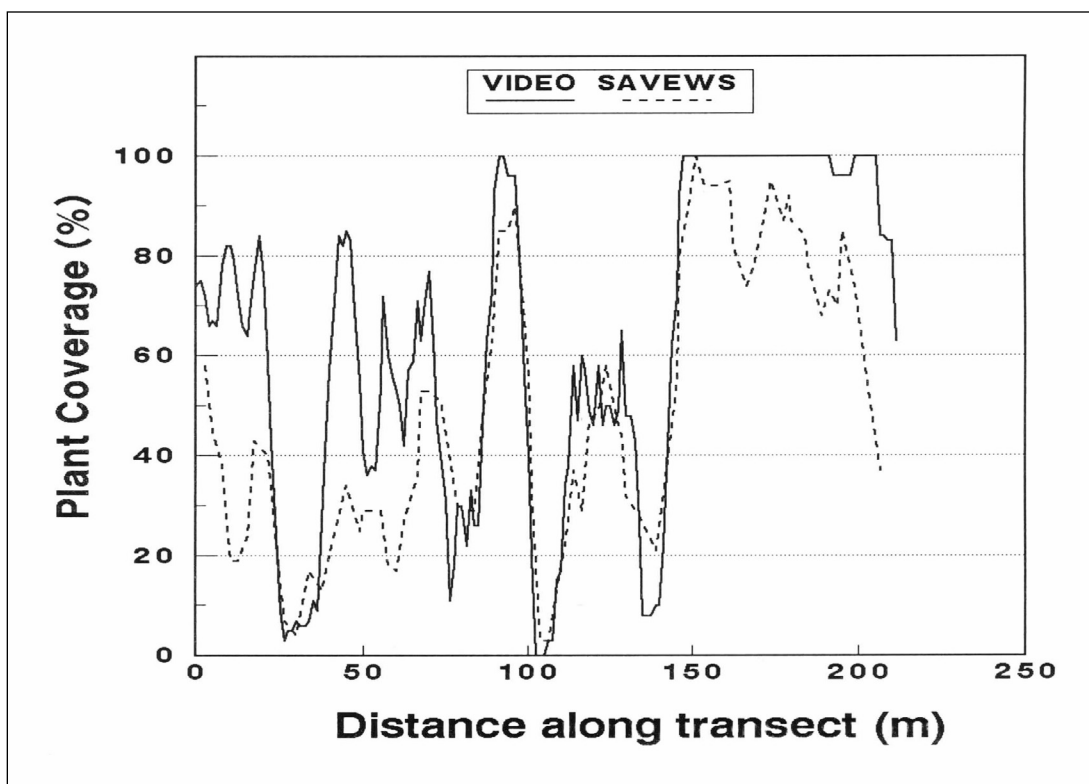
Figure D2. Hypothetical comparison of diver and acoustic measurements for a 2.5-m linear segment of SAV.





One could easily envision scenarios where there are dramatic differences between diver and acoustic survey technique results. An example of this would be surveys in sparse vegetation below the detection limit of the acoustic system – such as sparse and short *Halodule* spp. or *Halophila* spp. When operating in vegetation within the performance bounds of the acoustic system, results have been found to be generally similar. Simultaneous diver and acoustic data have been collected and analyzed for SAVEWS (Figure D3); however, this has not yet occurred for the SAVEWS Jr. system. The data in Figure D3 compare SAVEWS with simultaneous interpreted underwater video for a southwest Florida site containing a mixed bed of *Halodule*, *Syringodium*, and *Thalassia* (Sabol et al. 2002). The acoustic system was found to generate coverage estimates that were highly correlated, but slightly below, that of the videographic technique; there was, however, very good agreement on boundaries. While similar validation data are not yet available for the SAVEWS Jr. system, simultaneous comparisons with the SAVEWS system found a high level of agreement. SAVEWS Jr. is expected to exhibit a level of agreement that is at least similar to the standard SAVEWS coverage measures.

Figure D3. Comparison of interpreted underwater videography and SAVEWS acoustic system in a mixed seagrass bed in southwest Florida.



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14. ABSTRACT This user's manual describes components, assembly, system configuration, data collection procedures, and data processing activities for the second iteration of the Submersed Aquatic Vegetation (SAV) Early Warning System (SAVEWS Jr.). SAVEWS Jr. uses two frequencies (200- and 800-kHz) from a downward-aimed echo sounder to determine the bottom depth and presence/absence of SAV. If SAV is present, canopy height and vegetation percent coverage are estimated. Once collected, the digital data (Lowrance proprietary .SL2 files) are displayed, using the SAVEWS Jr. software. Users then select a configuration file that is appropriate to the environment sampled. A general version of this file is provided with the installation software to serve as a starting point for users to develop their own customized files.  After initial processing, a display of classified output (bottom depth and canopy top) is superimposed on the colorized echogram and aligned with data plots of canopy height and percent coverage. Beyond quality assurance graphics, the primary output of SAVEWS Jr. is the .SDF file (SAVEWS data file) which is an ASCII, comma-delimited file containing position-referenced classified output. This can be used directly in statistical analyses or mapping software.					
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